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Revision 0

Emergency Preparedness Hazards Assessment for Saltstone Facility

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DISCLAIMER

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LIST OF ACRONYMS

ARF	Airborne Release Fraction
ARP	Actinide Removal Process
ARR	Airborne Release Rate
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CIF	Consolidated Incineration Facility
CTF	Central Training Facility
DBA	Design Basis Accident
DCF	Dose Conversion Factor
DDE	Deep Dose Equivalent
DOE	Department of Energy
DR	Damage Ratio
DSA	Documented Safety Analysis
EAL	Emergency Action Level
EDO	Emergency Duty Officer
EG	Evaluation Guideline
EMG	Emergency Management Guide
EMPP	Emergency Management Program Procedures
EPA	Environmental Protection Agency
EPHA	Emergency Preparedness Hazards Assessment
EPIP	Emergency Plan Implementing Procedure
EPZ	Emergency Planning Zone
ERPG	Emergency Response Planning Guide
ETF	Effluent Treatment Facility
FB	Facility Boundary
GE	General Emergency
LCS	Low Curie Salt
MAR	Material at Risk
PAC	Protective Action Criteria

LIST OF ACRONYMS (Continued)

PPA	Property Protection Area
PrePAC	Precautionary Protective Action Criteria
Pu-238eq	Plutonium-238 Equivalent
RD	Release Designation
RF	Respirable Fraction
SAE	Site Area Emergency
SB	Site Boundary
SCDHEC	South Carolina Department of Health and Environmental Control
SDF	Saltstone Disposal Facility
SFT	Salt Feed Tank
SHT	Saltstone Hold Tank
SPF	Saltstone Production Facity
SRS	Savannah River Site
SQ	Screening Quantity
ST	Source Term
TEDE	Total Effective Dose Equivalent
TEL	Threshold for Early Lethality
TSR	Technical Safety Requirement
WAC	Waste Acceptance Criteria
WMA	Wildlife Management Area
WSP	Waste Solidification Projects
WSMS	Washington Safety Management Solutions
WSRC	Westinghouse Savannah River Company

LIST OF ABBREVIATIONS

C	Celsius (temperature)
cal	calorie
Ci	Curies
F	Fahrenheit (temperature)
ft	feet
gal	gallons
hr	hour
J	Joule
K	Kelvin degree
k	kilo (10^3)
kW	kilowatt
lb	pound
min	minutes
mm Hg	millimeters of mercury (pressure)
m	meter, or milli (10^{-3})
p	pico (10^{-12})
psig	pounds per square inch - gauge
ppm	parts per million (by weight)
vol%	volume percent
wt%	weight percent (concentration)
µ	micro (10^{-6})

1.0 INTRODUCTION

1.1 PURPOSE

This report documents the Emergency Preparedness Hazards Assessment (EPHA) for the Saltstone Facility. This EPHA was conducted in accordance with Emergency Management Program Procedure (EMPP) 6Q-001 (Ref. 1) and U.S. Department of Energy (DOE) Order 151.1A (Ref. 2), and guidance from DOE G 151.1-1 (Ref. 3). The purpose of this EPHA is to provide the technical basis for facility emergency planning efforts.

1.2 SCOPE

The EPHA scope includes Saltstone Facility on the DOE Savannah River Site (SRS) (Ref. 4). The Saltstone Facility is currently considering the option of processing low-level waste from difference sources. This evolution would require revised operating permits from South Carolina Department of Health and Environmental Control (SCDHEC). The maximum expected permit concentrations that will be provided to SCDHEC when SRS requests the new operating permits for the wastewater treatment facility (Saltstone Production Facility) and the industrial solid waste landfill (Saltstone Disposal Facility) are given in document WSP-SSF-2004-00015 (Ref. 5). This document recommended Saltstone facility radiological and chemical waste acceptance criteria (WAC) and permit limits for development of Tank 50H material balance.

1.3 BACKGROUND

The EPHA methodology specified in EMPP 6Q-001 (Ref. 1) differs from that used in other facility safety documentation (e.g., Documented Safety Analysis [DSA], Hazard Assessment Document, or Basis for Interim Operation). The EPHA uses barrier analysis as opposed to risk or probabilistic analysis. This method involves compilation and screening of facility radiological and chemical inventories. For materials that exceed screening thresholds, hazard characterization and barrier identification are performed. Then, event scenarios ranging from minor to severe (e.g. beyond design basis) are postulated. Scenarios specify release mechanism, duration of release, and respirable source term. From these scenarios, consequence assessments are performed to determine the downwind dose or concentration at defined receptor locations.

DSAs provide analyses and consequences for the worst credible accidents (Design Basis Accidents [DBAs]). These analyses are used to determine design and performance specifications of safety features. DBAs and their associated assumptions can be used as a starting point for emergency response planning; however, their use may be limited because they contain many conservative assumptions that may not be appropriate. For example, unlike a DSA, an EPHA is not required to use a “bounding” analysis; rather, EPHA analysis must meet the standard of “conservative.” For example, a maximum tank inventory may be based on maximum operating history rather than physical capacity.

The DSA sets a safety envelope that essentially covers accidents over the design basis spectrum. The result is to have controls in place (e.g., Technical Safety Requirements [TSRs], qualified structures, procedures, etc.) to demonstrate if a specific event will occur or not, and, if it occurs, the risk to workers and the public is acceptable. The EPHA quantitatively documents consequences for all events based on a barrier challenge/failure analysis (deterministic analysis). The evaluation guide for an EPHA is uniform (at 1 rem) over the entire spectrum of events.

In a DSA, an unmitigated release might be postulated to determine if Evaluation Guidelines (EGs) could be exceeded. If an EG is exceeded, the accident analysis may credit mitigation features that reduce the impact of the accident. This analysis would include the justification for these features and how they are maintained (e.g., via TSRs) to reduce risk to an acceptable level. No such credit requirement exists for the EPHA. EPHA accident analysis is not based on unmitigated accidents. An EPHA may credit operator intervention using a criterion of “reasonable” response. This is why an EPHA typically assumes a spill response time of 10 minutes rather than longer times typically assumed in the DSA. The EPHA may eliminate accidents from consideration if the initiator is of sufficient length that operator intervention might reasonably occur. For example, the EPHA might assume that workers would terminate a transfer before waste tanks fill and begin to overflow since it takes many hours for this accident to occur.

The EPHA is required to address malevolent acts (Ref. 1). The DOE Emergency Management Guide (EMG) for Hazards Assessments defines two degrees of malevolent acts: moderate and extreme (Ref. 3). Both moderate and extreme events are addressed in the facility’s Safeguards and Security document (Ref. 6). In most cases, malevolent acts will produce releases and consequences similar to those that could be caused by other initiators. For example, the catastrophic failure of a chemical storage tank might be postulated due to a seismic or tornado event. However, if approximately the same level of damage and source term might also be caused by an act of sabotage, such as running a motor vehicle into the tank, the malevolent act would simply be considered another initiator for the failure of the storage tank.

Finally, Emergency Action Levels (EALs) and the facility Emergency Planning Zone (EPZ) are determined from these results. Events capable of exceeding defined Protective Action Criteria (PAC) at receptor locations are assigned an emergency classification. Based on consequence assessment, a facility Emergency Plan Implementing Procedure (EPIP) will be written for use by facility personnel to accurately classify events in a timely manner.

1.4 REVISION SUMMARY

Revision 0 addresses the following:

- Saltstone Facility EPHA was part of the EPHA for the Consolidated Incineration Facility (CIF), Effluent Treatment Facility (ETF) and Saltstone Facility, S-EHA-G-00004 (Ref. 7). CIF and ETF are no longer part of this EPHA. Previous development of Saltstone Facility EPHA could be obtained in S-EHA-G-00004 (Ref. 7).
- This was a complete stand alone revision; therefore, revision bars are not incorporated.
- Updated radiological and chemical inventories.
- Updated EPHA based on the current EPHA Style Guide.
- Incorporated recommendations from the latest Saltstone EPHA annual review (Ref. 8).
- Addressed malevolent acts.
- Removed the Barrier Identification section.
- Added security event EALs.
- Added Appendix D, Committed Effective Dose Equivalent (CEDE) versus Total Effective Dose Equivalent (TEDE).
- Added Appendix E, Emergency Operation Center Technical Support Room Data.

2.0 SUMMARY

An EPHA was conducted for Saltstone facility in accordance with EMPP 6Q-001 (Ref. 1). Analysis included the following:

- Compilation, screening, and hazard characterization of chemical and radiological materials
- Barrier identification
- Accident scenario development for potential releases of identified hazardous materials
- Consequence assessment of the identified scenarios
- Emergency classification development
- Determination of the facility EPZ

Materials present within Saltstone that require analysis are:

- Chemicals: None
- Radionuclides: Sr-90, Cs-137, Pu-239, Pu-241, Th-232, U-233, U-234, U-236 and U-238

For the materials identified above, accident scenarios were identified that may exceed the specified PAC at the downwind receptor points of interest. For each scenario identified, a consequence assessment and corresponding EAL determination was made. The results show the potential for the following:

	Radiological	Chemical
General Emergencies (GE)	0	0
Site Area Emergencies (SAE)	0	0
Alerts	0	0

For materials identified above, accident scenarios were postulated. For each scenario, consequence assessment was performed. Results did not show a potential for classifiable operational emergencies. As such, EPIPs are not required for Saltstone. Therefore, determination of a facility EPZ is not required.

3.0 FACILITY DESCRIPTION

3.1 SALTSTONE FACILITY

The Saltstone Facility is located in Z Area. The facility treats waste water containing low levels of radioactive contaminants to convert these solutions to a grout suitable for disposal in large concrete vaults located within Z Area. Grout is pumped from the facility into a vault where it solidifies into a monolithic solid waste form known as Saltstone. Interrelated operations within Saltstone are described below.

3.1.1 Salt Feed Tank

The Saltstone Facility contains two facility segments: The Saltstone Production Facility (SPF), which produces saltstone grout; and the Saltstone Disposal Facilities (SDF), which consists of vaults used for disposal of the saltstone grout. The SPF and SDF are part of the Waste Solidification Projects (WSP) facilities. The Saltstone Facility is actually one portion of an integrated waste management and disposal system located at SRS. This integrated system is designed to treat liquid waste that was generated and stored at SRS, and convert the waste into solid waste forms suitable for final disposal. The SPF and SDF are a critical part of this system because they are used to treat and dispose of low-activity mixed liquid waste generated by other waste treatment facilities that are also part of the integrated system. The Saltstone Facility will be used to treat and safely dispose of more than 90% of the waste (by volume) that will be generated from the treatment of liquid waste presently stored in waste tanks. The Saltstone Facility primarily treats low-activity wastewater generated by the ETP, the Low Curie Salt (LCS) process, and the Actinide Removal Process. Low-activity wastewater from these processes is stored in Tank 50 until it is pumped to the Saltstone Facility for treatment and disposal. Low activity wastewater from other sources may also be transferred to Tank 50 for processing as long as the waste transferred to the Saltstone Facility meets the requirements of the Saltstone Facility WAC.

The Salt Feed Tank (SFT) is the receipt point for the waste from these other facilities. Waste is transferred through an underground Inter-Area Transfer Line with a jacketed arrangement (pipe within a pipe) for spill/leak control. The SFT capacity is limited to 6504 gallons by an overflow line. The SFT is located in a 1 foot thick reinforced concrete dike. The dike extends approximately 16 feet below grade and 8 feet above grade. There is an access opening at grade level. Waste water from the SFT is provided to the Saltstone Mixer along with the Saltstone dry mix chemicals to produce Saltstone grout.

3.1.2 Bulk Material Handling

Cement, slag, and fly ash (Saltstone dry mix chemicals) are delivered via truck. The dry material is conveyed pneumatically to four identical silos (6.7 m in diameter and 17.7 m high). The materials are blown directly to the silos using compressed air from the truck's compressor. One silo contains cement, one contains slag, one contains fly ash, and one is a spare. The dry feeds are combined in a weigh hopper and transferred to a premix air blender. From the blender, the mixture is transferred to the Premix Feed Bin located on the roof of the Process Building. Premix is fed to a screw feeder that controls the flow of the dry material to the mixer where it is combined with waste water to form grout.

3.1.3 Saltstone Mixing and Transfer

Premix from the Premix Feed Bin and waste water are mixed in the Saltstone Mixer to produce Saltstone grout. Grout discharges from the mixer into Saltstone Hold Tank (SHT), which gravity feeds the grout pump system.

3.1.4 Saltstone Disposal

Grout is pumped from the process area to concrete vaults via a pipeline. Each filled cell is layered with clean concrete. A pig launching system is utilized for cleaning the grout transfer line during transfer shutdown. An online launcher uses compressed air to launch a rubber ball (‘pig’). The pig wipes the inside of the pipeline and forces any grout into the vault. Air is expelled in the vault.

3.2 FACILITY BOUNDARY

The Facility Boundary (FB) is determined in accordance with EMPP 6Q-001 and differentiates between an Alert and SAE for each facility (Ref. 1). The FB is the Property Protection Area (PPA) security fence. If the fence is closer than 100 meters, the default distance is 100 m (Ref. 1). Distances of 130 m for Saltstone Facility (nearest boundary) were chosen as the FB for all release scenarios.

3.3 SITE BOUNDARY

The Site Boundary (SB) is normally defined as the perimeter of DOE-owned and controlled land at SRS. From EMPP 6Q-001 (Ref. 1), the minimum distance from Saltstone Facility to the nearest SB is 9.98 km.

3.4 OTHER RECEPTORS OF INTEREST

In addition to the typical receptor locations used for emergency classifications (30 meter, FB, SB), consequences to other adjacent facilities with significant personnel occupancy are also considered in this EPHA. One such facility is the Central Training Facility (CTF), which serves as the site centralized training facility. The CTF, Building 766-H, is located in H Area, north of H Separations; between the Tritium Facility and the Defense Waste Processing Facility and is designed to house approximately 1,600 personnel. Its distance to Saltstone Facility is 1,200 m (Ref. 4). Also considered is the Crackerneck Wildlife Management Area (WMA) (Ref. 9). The Crackerneck WMA is located south of Jackson off SC 125 and is bounded by Upper Three Runs Creek, the Savannah River and the site boundary. The WMA is located approximately 9,660 m from Saltstone Facility.

4.0 IDENTIFICATION AND SCREENING OF HAZARDS

The objective of this section is to identify hazards that are significant enough to warrant consideration in a facility's operational emergency hazardous material program. Note that “hazard”, as used in this section, refers to both non-radioactive hazardous materials and radioactive material.

Screening quantities or thresholds are used to eliminate the need to analyze insignificant hazards.

Facility chemical and radiological inventories are obtained from WSP-SSF-2004-00015 (Ref. 5). Hazards associated with transportation to, from, or through, the facility boundaries that could have an impact on the health and safety of personnel are also considered. Once facility inventories are established, hazard screening and characterization is completed. It eliminates from further analysis those materials that do not present an airborne toxic hazard.

4.1 NON-RADIOACTIVE MATERIALS

The inventory of chemicals is screened from further analysis based on criteria in EMPP 6Q-001 (Ref. 1), which states, “eliminate chemicals not present in quantities exceeding Threshold Quantities (TQs) listed in either 29 CFR 1910.119 or 40 CFR 68.130 or Threshold Planning Quantities (TPQs) listed in 40 CFR 355” (Refs. 10, 11, 12).

Chemical inventories were separated by categories, as indicated below, in order to facilitate the inventory and characterization process.

- Purchased chemicals
- Process chemicals
- Reactive Chemicals

4.1.1 Purchased Chemicals

Purchased chemicals were evaluated in Calculation 1 - Appendix B of this EPHA. Purchased chemicals are chemicals purchased and brought into the facility. All purchased chemicals for Saltstone were eliminated from further analysis.

4.1.2 Process Chemicals

Process chemicals were evaluated in Calculation 1 - Appendix B of this EPHA. Process chemicals are defined as chemical species contained in the process liquid streams. All process chemicals were screened by physical properties or were present in amounts less than the allowable maximum inventory.

4.1.3 Reactive Chemicals

There is no danger of an uncontrolled, process-related chemical reaction in Z-Area. When the salt solution is added to a blend of slag, fly ash, and cement, the principal chemical reaction that occurs is simply the hydration of the dry materials that leads to the formation of the solid grout. The salt solution will not degrade or decompose because the chemicals are stable in aqueous solutions at a pH greater than seven. The pH of the salt solution in Tank 50H is maintained in the alkaline state by the Concentration, Storage, and Transfer Facilities Corrosion Control Program. No reactive chemicals are added to the salt solution during saltstone processing.

4.1.4 Results of Chemical Screening

No chemicals in Saltstone Facility required further analysis.

4.2 RADIOLOGICAL MATERIALS

4.2.1 Radiological Inventory

Inventories for Saltstone Facility are given in Calculation 2 - Appendix B.

4.2.2 Radiological Screening

Radionuclides are screened using the screening quantities listed in the Code of Federal Regulations (CFR) 10 CFR 30.72 and employing the methodology identified in DOE STD-1027 (Ref. 13, 14). If the sum of all the ratios of the inventory of each nuclide to that radionuclides screening quantity is greater than or equal to one, then none of the radionuclides can be screened:

$$\sum_{i=1}^{n} \frac{r_i}{SQ_i} \geq 1.0 \qquad \text{[Eq. 4-1]}$$

where:

	r	=	Radionuclide
	SQ	=	Screening Quantity for individual radionuclide (Ci)
	n	=	Number of radionuclides

If the inventory for a building is unable to be screened, radionuclides present in the inventory may be eliminated from further consideration if the dose contribution of a radionuclide does not significantly contribute to the cumulative dose of the entire inventory.

4.2.3 Radiological Materials Screening Results

The radiological content of Saltstone Facility liquid waste is above the Screening Quantities listed in 10 CFR 30.72, Schedule C. Therefore, Saltstone Facility inventory is retained for further analysis. The Pu-238eq was determined based on major contributors to dose and is given in Appendix B, Calculation 2.

4.3 HAZARDOUS MATERIAL REQUIRING FURTHER ANALYSIS

After applying the methodologies described above for Saltstone chemical and radionuclide inventories, hazards requiring further analysis are determined. Table 4.1 indicates hazards requiring further analysis.

Table 4.1 Hazards Requiring Further Analysis

Chemicals	Radionuclides
None	Sr-90, Cs-137, Pu-239, Pu-241, Th-232, U-233, U-234, U-236 and U-238

4.4 PROTECTIVE ACTION CRITERIA (PAC) FOR REMAINING HAZARDS

Two radiological PACs are used in Emergency Planning at SRS (Ref. 1). The first PAC, 1.0 rem TEDE or 5 rem Effective Dose Equivalent (EDE) Thyroid, is the threshold, at specific receptors, for declaration of a classifiable operational emergency. The last, 100 rem, is the threshold for early lethality (TEL) and is an input to facility Emergency Planning Zone (EPZ) determination.

Table 4.2 Radiological PAC

PAC Name	Value (rem)
Operational Emergency	1 rem
Threshold for Early Lethality	100 rem

5.0 ACCIDENT ANALYSIS

Barriers that maintain control over the hazardous materials that failed initial screening/hazard characterization have been analyzed and possible failure modes considered. Results of barrier analysis and resulting release designations are described in this section. Section 6.0 contains a summary of the consequences from each release designation.

Within Section 5.0, potential events that would challenge a barrier are not normally described in detail, as the list can become quite long. A list of potential accident initiators will be identified for each barrier failure but is not intended to be an exhaustive listing. Details of various accident initiators are described in the *Saltstone Facility Documented Safety Analysis* (Ref. 15).

The accident initiator is not an essential factor in the development of EALs, which are the end product of an EPHA. Many accident initiators will often produce the same barrier failure and consequence. How an accident originated may not be decisive in the recognition and categorization of an event. In those cases where the accident initiator has a direct bearing on the source term and the consequences the initiator is identified and described. If events are identified where the only initiator to a release is a malevolent act, it is explicitly stated in the EPHA.

The method used to transform inventories of hazardous materials into source terms is as follows:

- Determine barrier failure modes by identifying initiating events.
- For each failure mode, determine mechanisms for release.
- Based on release mechanisms, a quantitative estimate of the material at risk is developed, considering the nature of the material (physical state, vapor pressure, etc.) and the postulated mode of failure.
- Source term is then calculated by applying release fractions for each event.

<u>Source Terms</u>

DOE-HDBK-3010-94 (Ref. 16) provides Airborne Release Fractions (ARFs), Respirable Fractions (RFs), and Airborne Release Rates (ARRs) applicable to many types of releases. The median ARF/RFs, and ARRs listed in DOE-HDBK-3010 are normally most appropriate for use in EPHAs. The final source term (ST) is calculated as follows:

ST = (MAR) (DR) (ARF) (RF) (LPF) [Eq. 5-1]
or
ST = (MAR) (DR) (ARR) (t) (RF) (LPF) [Eq. 5-2]

Where,

ST	=	Source Term
MAR	=	Material at Risk
DR	=	Damage Ratio (fraction)
ARF	=	Airborne Release Fraction
RF	=	Respirable Fraction
LPF	=	Leak Path Factor (fraction)
ARR	=	Airborne Release Rate (fraction/hour)
t	=	Release Duration (hours)

Since the purpose of this EPHA is to determine the emergency-planning basis in regards to the initial phases of an event (identification, classification, and initial protective actions), the resuspension source term will not be calculated or utilized.

5.1 SALTSTONE

5.1.1 Chemical Releases

No chemical releases have been identified.

5.1.2 Radiological Releases

The accident analyses for radiological releases from Saltstone Facility are developed in Calculation 3 of Appendix B and are summarized below.

5.1.2.1 Salt Feed Tank Spill

Failure of the Primary Barrier

Primary barrier for Salt Feed Tank is the tank wall.

Effects of Other Barriers/Mitigative Features
Administrative mitigative features include small batch processing and operators monitoring all transfers.

Range of Possible Releases

Breach of a tank scenario is considered for Saltstone Facility in which the SFT catastrophically fails spilling its contents (6504 gallons). The median ARF (4E-5) and RF (0.7) were chosen from DOE Handbook 3010, Page 3-4 (Ref. 16). A free-fall spill was assumed with the solution having a density ~ 1.0 g/cm^3 (3-m fall distance). A DR and LPF of 1 are assumed. This is an unfiltered release at ground level with a release duration of 10 minutes. The source term for postulated spill is given below. More information is given in (Appendix B, Calculation 3).
Release Designation 1-RD-1.

Source Term for Salt Feed Tank Spill Scenario						
Release Designation	**MAR (Ci)**	**DR**	**ARF***	**RF***	**LPF**	**Source Term (Ci)**
1-RD-1	6.60E+00	1	4.00E-05	0.7	1	1.85E-04

5.1.2.2 Salt Feed Tank Explosion

Failure of the Primary Barrier

Primary barrier for Salt Feed Tank is the tank wall.

Effects of Other Barriers/Mitigative Features
Administrative mitigative features include small batch processing and operators monitoring all transfers.

Range of Possible Releases

A postulated explosion scenario is considered for Saltstone Facility in which the ventilation of the SFT fails and allows the benzene to build up. The scenario involves a waste tank full of vapor space, a benzene concentration of 2.72 vol % in the vapor space, and 1.0 g/cm^3 liquid density.

A deflagration was assumed instead of a detonation. Lees (Ref. 17) states that while detonations may occur in pipelines, they are improbable in vessels. In non-baffled vessels there are no obstructions causing turbulence and flame acceleration. Transition to detonation is therefore not likely in vessels, unless the gas is very detonable, the gas cloud is large, the cloud is jet ignited, or the vessel contains obstacles. In addition, the indicators for an explosion would be the same whether a detonation or a deflagration.

The model states that the energy from the deflagration is used to vaporize the solution. The MAR x DR is the amount of liquid vaporized. As the liquid is vaporized, an amount equal to 0.1 of the vaporized liquid will become aerosolized (ARF= 0.1) and all the airborne particles are assumed to be respirable (RF=1). Since there was no credit taken for any aerosol removal mechanism, the LPF is conservatively assumed to be 1.

This is an unfiltered release at ground level with a release duration of 3 minutes. The source term for postulated explosion is given below. A more detail calculations are given in (Appendix B, Calculation 3). **Release Designation 1-RD-2.**

Source Term for Salt Feed Tank Explosion Scenario							
Release Designation	**Pu-238 eq * (ci/gal)**	**ST (kg)**	**Density (g/cm^3)**	**ARF*RF**	**DR**	**LPF**	**ST (Ci Pu-238 eq)**
1-RD-2	1.02E-03	10.06	1.0	0.1	1	1	2.69E-04
* - 6.60E+00 Ci/6504 gal							

5.1.3 Hazardous Materials in Saltstone Requiring No Further Analysis

- Analyzed scenarios bound those involving smaller inventories.
- A fire is not foreseen inside the SFT. Fire is a concern only if both fuel (e.g., combustible material) and waste is present concurrently in the tank and a credible ignition source is available. The fire event is not reasonably anticipated to occur during normal operations.

- No additional material is stored in Saltstone Facility that would require further consideration in this EPHA.

5.2 MALEVOLENT ACTS

The evaluation of Malevolent acts is directed in EMPP 6Q-001 (Ref. 1) and the EMG (Ref. 3). The EMPP 6Q-001 states:

> *"Malevolent acts (theft, sabotage, terrorism) including the use of explosives or flammable material are possible release initiators within the scope of emergency planning. It is not intended that all inventories be evaluated with malevolent event initiators. Both moderate and extreme scenarios should be developed and analyzed to establish EALs for events resulting from malevolent acts."*

In most cases, malevolent act events will produce releases and consequences similar to those that could be caused by accidental or other external initiators. For example, the catastrophic failure of a shipping cask might be postulated due to a seismic or tornado event. The same failure of the shipping cask caused by a malevolent act would result in the same consequences; therefore, the malevolent act is considered another initiator for the failure of the cask.

The potential impact of Malevolent Acts affecting the Saltstone Facility was evaluated by the WSRC Safeguards & Security Vulnerability Analysis Group (Ref. 6). Using the Design Basis Threat as defined by DOE, two (2) types of event scenarios were analyzed, an "extreme" event and a "moderate" event. The extreme event scenario provides an upper bound on the severity of potential consequences. The extreme event is based on the full spectrum of adversary capabilities. The "moderate" event scenario is described in the EMG for Hazard Surveys and Assessments (Ref. 3) as; *" those that could be initiated by a single individual using materials or tools readily available in the facility, or small quantities of flammables. "*

5.2.1 Moderate Events

The accident analysis conducted in section 5.1 evaluated the release from SFT spill or explosion scenarios. These events bound any postulated moderate malevolent events and their consequences. Both of the scenarios did not result in doses exceeding PAC at 30 meters and the release mechanism is covered by the barrier failure analysis previously conducted.

5.2.2 Extreme Events

As addressed previously for the moderate events, both scenarios cannot exceed PAC at 30 meters and the release mechanism is covered by the barrier failure analysis previously conducted. Therefore, based on this assessment of malevolent acts, the EAL for the moderate and extreme events will be to declare an operational emergency when a Phase IV Security Declaration is made.

5.3 ACCIDENT SUMMARY

Table 5.1 summarizes the accidents presented within this section based on release designation.

Table 5.1 Accident Summary

Release Designation	Accident Scenario
1-RD-1	SFT in Saltstone Facility spills due to rupture of the tank
1-RD-2	SFT in Saltstone Facility release due to an explosion

6.0 CONSEQUENCE ASSESSMENT

This section provides an overview of the methodology and presents results of analysis used to transform accident scenarios identified in Section 6.0 into projected ground-level concentrations at previously identified receptor locations.

6.1 DESCRIPTION OF METHODOLOGY

6.1.1 Radionuclide Dispersion Modeling

The HOTSPOT (Ref. 18) dispersion code was used for dispersion modeling of all radiological releases. The HOTSPOT dispersion code is a Gaussian plume model developed by the DOE for emergency planning activities.

6.1.2 Chemical Dispersion Modeling

Releases of hazardous chemicals are modeled using ALOHA (Ref. 19). ALOHA utilizes both a straight-line Gaussian model and a heavy gas computation model. ALOHA is used for dispersion modeling of chemical releases in accordance with the guidance in EMPP 6Q-001 (Ref. 1). Meteorological conditions used are consistent with the guidance in EMPP 6Q-001.

6.1.3 Dispersion Modeling Parameters

Distances to receptor locations:

- Alert = 30 meters from the release
- SAE = 130 m
- GE = 9980 m

Meteorology:

Temperature and inversion layer height:

Inversion Layer: 300 meters (E stability class) (Ref. 20)
500 meters (B, C, and D stability class) (Ref. 20)

Temperature: 29°C (All stability classes, 95% adverse meteorology)
25°C (All stability classes, average meteorology)

Stability classes and wind speeds are as follows:

95% Adverse - Ground level releases (≤10 m) - E Stability with 1.7 m/s wind speed (2 m reference height)

Average - Stability Class and Wind Speed for all receptors:

C Stability Class with 2.5 m/s wind speed

Terrain

City terrain (100 cm) is representative of ground roughness for SRS.

Deposition Velocity

A deposition velocity of 1.0 cm/s is used.

Release Duration

Duration of a fire for HOTSPOT is 10 minutes for spill and 3 minutes for explosion scenario.

6.2 EVENT CLASSIFICATION DETERMINATION

Consequence Assessment results are evaluated against the following criteria to determine the appropriate emergency class for the event scenario (Ref. 1):

1. Thirty meters from the release (or edge of spill). Dose/concentration at this receptor location provides the demarcation between an accident that would require emergency response organization involvement (e.g., Alert) and one that would not.

2. Distance from the release to the nearest facility boundary. The facility boundary is the demarcation between the facility and its immediate vicinity and the remainder of the site. Dose/concentration at this receptor location provides the demarcation between an Alert and SAE.

3. Distance from the release to the closest site boundary. Dose/concentration at this receptor location is the demarcation for a GE declaration.

4. Operational Emergency – An event or condition that poses a significant hazard to safety, health, and/or the environment and requires time-urgent response from outside the facility. An Operational Emergency involving the release of significant quantities of hazardous materials may require further classification as an Alert, SAE or GE. The Emergency Duty Officer (EDO) in the SRS Operations Center is the Site categorization and reporting authority for Operational Emergencies that do not require further classification.

5. Courtesy Notification Event – An event or condition that does not fall within the Operational Emergency categorization and classification system but has the potential for significant public or media interest.

In each zone, releases are evaluated to determine if PAC has been exceeded. The last zone where a PAC is exceeded determines event classification. The PAC is a personnel radiation exposure level (1 rem TEDE) or toxic chemical concentration (peak 15-minute average) equal to ERPG-2.

Distance to a precautionary protective action trigger for non-essential personnel (0.1 rem or ERPG-1), or PrePAC (Ref. 21), is determined only for events that exceed PAC at defined receptor locations.

Although the radiological PAC is defined in terms of TEDE (external dose plus internal dose), HOTSPOT calculates CEDE. The CEDE is the 50-year committed dose from inhalation of radionuclides. For non-reactor type accidents, the CEDE is by far the major portion of the TEDE and may be considered equivalent for EPHA purposes as given in Appendix E (Ref. 22, 23).

6.3 CONSEQUENCE ASSESSMENT RESULTS

Tables 6.1 contains consequence assessment results for releases described in Section 6.0 under adverse (95%) meteorological conditions. Results from Appendix B, Calculation 3 are summarized in these tables. Also, as no PACs are exceeded, distances to PrePAC are not determined. Consequences for Average meteorological conditions are not needed since the Adverse meteorological conditions do not exceed the PAC for a given scenario.

Table 6.1 Adverse Consequence Assessment Results - Radiological

Table 5. Consequence Assessment Results								
Release Designation	**Met.**	**Dose @ 30 meters (rem)**	**Dose @ FB (rem)**	**Dose @ CTF (rem)**	**Dose @ WMA (rem)**	**Dose @ SB (rem)**	**Max. Distance to 1 rem (meter)**	**Probable Event Class**
1-RD-1	Adverse	2.8E-01	2.5E-02	5.4E-04	3.3E-05	3.1E-05	10	None
1-RD-2	Adverse	5.2E-01	4.6E-02	1.0E-03	6.0E-05	5.8E-05	20	None
Met. = Meteorology								

7.0 EMERGENCY CLASSES AND EMERGENCY ACTION LEVELS

Since consequence assessment did not identify any Classifiable Operational Emergencies (i.e., PAC are not expected to be exceeded at identified receptor locations), EALs are not required for Saltstone Facility. In the case of an abnormal event, go to the Saltstone Facility Abnormal Operating Procedures Manual, SW 24.4 (Ref. 24).

8.0 EMERGENCY PLANNING ZONE DETERMINATION

Since no SAEs or GEs are postulated, an EPZ is not required for Saltstone Facility.

9.0 REFERENCES

1 *Standards for Development and Maintenance of an Emergency Preparedness Hazards Assessment*, EMPP 6Q-001, Revision 4, Westinghouse Savannah River Company, Aiken, SC, July 2002.

2 *Comprehensive Emergency Management System*, DOE Order 151.1A, U.S. Department of Energy, Washington, DC, November 1, 2000.

3 *Emergency Management Guide – Vol. II, Hazards Surveys and Hazards Assessments*, DOE G 151.1-1, U.S. Department of Energy, Washington, DC, August 1997.

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5 Chandler, T.E., *Recommended Saltstone Facility Radiological and Chemical WAC and Permit Limits for Development of Tank 50H Material Balance (U)*, WSP-SSF-2004-00015, Rev. 1, Westinghouse Savannah River Company, Aiken, SC, July 15, 2004.

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7 *The Emergency Preparedness Hazards Assessment for Consolidated Incineration Facility (CIF), Effluent Treatment Facility (ETF) and Saltstone Facility*, S-EHA-G-00004, Rev. 3, Westinghouse Savannah River Company, Aiken, SC, September 2003.

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9 Martin, A.R., *SRS Facility Impacts on Crackerneck Wildlife Management Area*, WSRC-TR-99-00417, Westinghouse Savannah River Company, Aiken, SC, Nov. 1999.

10 *Labor*, *Process Safety Management of Highly Hazardous Chemicals*, Code of Federal Regulations, 29 CFR, Part 1910.119, U.S. Department of Labor, July, 1999.

11 *Protection of Environment, Accidental Release Prevention Requirements*: Risk Management Programs Under Clean Air Act, 40 CFR 68, U.S. Environmental Protection Agency, Washington, DC, July 1999.

12 *The List of Extremely Hazardous Substances and Their Threshold Planning Quantities*, 40 CFR 355, U.S. Environmental Protection Agency, Washington, DC, July 1999.

13 *Quantities of Radioactive Materials Requiring Consideration of the Need for an Emergency Plan for Responding to a Release*, Title 10 Code of Federal Regulations Part 30.72 Schedule C. U.S. Nuclear Regulatory Commission, Washington, DC, July 1, 2003.

14 *Hazard Categorization and Accident Analysis*, DOE-STD-1027-92, Change 1, U.S. Department of Energy, Washington, DC, September 1997.

15 *Saltstone Facility Documented Safety Analysis (U)*, WSRC-SA-2003-00001, Rev. 1, Savannah River Site, Westinghouse Savannah River Company, Aiken, SC, August 2003.

16 *Airborne Release Fractions/Rates and Respirable Fractions for Non-Reactor Nuclear Facilities, Volume I – "Analysis of Experimental Data"*, DOE-HDBK-3010-94, CN-1, U.S. Department of Energy, Washington, DC, March 2000.

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19 *Areal Locations of Hazardous Atmospheres (ALOHA)*. Version 5.2.2, National Oceanic and Atmospheric Administration, Environmental Protection Agency, Washington, DC.

20 Holzworth, G. C., *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States*, U. S. Environmental Protection Agency, Division of Meteorology, Research Triangle Park, North Carolina, January 1972.

21 *Savannah River Site Emergency Plan, Section 7, Protective Actions*, WSRC-SCD-7, Rev 2, Westinghouse Savannah River Company, Aiken, SC, November 3, 1997.

22 Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, U. S. EPA, EPA 400-R-92-001, October 1991.

23 Hadlock, D. J., *Pu-238 Resuspension Source Term Contribution to Total CEDE for all Phases of an Emergency Response*, ECS-EST-97-00010, Revision 0, Westinghouse Savannah River Company, Aiken, SC, July 21 1997.

24 *Saltstone Facility Abnormal Operating Procedures Manual*, SW 24.4, Westinghouse Savannah River Company, Aiken, SC.

Appendix A
Figures

Figures

None

Appendix B

Calculations

INTRODUCTION

The purpose of this calculation is to determine the Saltstone Facility chemical inventories and compare the inventory to threshold quantities. Review of the chemical inventory information is required by EMPP 6Q-001 (Ref. 1). Entries that require further characterization are summarized in the results.

INPUT DATA

Chemical inventories for Saltstone Facility are obtained from Reference 2 and are given in Table 1. The Saltstone Facility, Salt Feed Tank is assumed to hold 6504 gallons.

Table 1. Chemical Inventory for Saltstone Facility

Chemical Name	Chemical Formula	Molecular Weight (g/mol)	Bounding Concentration (mg/L)
Solvated Ions			
Aluminate	$Al(OH)_4^-$	95.01	6.62E+05
Ammonium	NH_4^+	27.02	9.50E+03
Carbonate	CO_3^{2-}	60.01	1.93E+05
Chloride	Cl^-	35.45	1.29E+04
Formate	$HCOO^-$	45.02	1.00E+04
Fluoride	F^-	19.00	6.58E+03
Hydroxide	OH^-	17.01	2.55E+05
Nitrate	NO_3^-	62.01	7.05E+05
Nitrite	NO_2^-	46.01	3.45E+05
Oxalate	$C_2O_4^{2-}$	88.02	4.40E+04
Phosphate	PO_4^{3-}	94.97	4.75E+04
Sulfate	SO_4^{2-}	96.06	9.19E+04
RCRA Hazardous Metals			
Arsenic	As	74.92	1.00E+03
Barium	Ba	137.3	1.00E+03
Cadmium	Cd	112.4	5.00E+02
Chromium	Cr	52.0	2.00E+03
Lead	Pb	207.2	1.00E+03
Mercury	Hg	200.6	5.00E+02
Selenium	Se	78.96	1.00E+03
Silver	Ag	107.9	1.00E+03
Other Metals			
Aluminum	Al	27	1.88E+05
Boron	B	10.81	1.20E+03
Calcium	Ca	40.08	3.68E+03
Cerium	Ce	140.1	1.20E+03
Cesium	Cs	132.9	1.20E+03
Cobalt	Co	58.93	1.20E+03
Copper	Cu	63.55	1.20E+03
Iron	Fe	55.85	8.00E+03
Lithium	Li	6.94	1.20E+03
Magnesium	Mg	24.31	1.20E+03
Manganese	Mn	54.94	1.20E+03

Table 1. Chemical Inventory for Saltstone Facility			
Chemical Name	**Chemical Formula**	**Molecular Weight (g/mol)**	**Bounding Concentration (mg/L)**
Molybdenum	Mo	95.94	1.20E+03
Neodymium	Nd	144.2	1.20E+03
Nickel	Ni	58.70	1.20E+03
Potassium	K	39.10	4.89E+04
Ruthenium	Ru	101.1	1.20E+03
Silicon	Si	28.09	1.72E+04
Sodium	Na	22.99	4.56E+05
Strontium	Sr	87.62	1.20E+03
Titanium	Ti	47.88	1.20E+03
Zinc	Zn	65.38	1.30E+03
Zirconium	Zr	91.22	1.20E+03
Suspended Hydrated-Sludge Solids			
Aluminum hydroxide	$Al(OH)_3$	78.00	1.93E+04
Barium sulfate	$BaSO_4$	233.36	1.59E+02
Chromium (III) hydroxide	$Cr(OH)_3$	103.02	1.59E+02
Iron (III) hydroxide	$Fe(OH)_3$	106.87	2.06E+04
Lead carbonate	$PbCO_3$	267.21	1.59E+02
Lead sulfate	$PbSO_4$	303.26	3.19E+02
Manganese dioxide	MnO_2	86.94	1.08E+04
Mercuric oxide	HgO	216.60	2.07E+03
Nickel hydroxide	$Ni(OH)_2$	92.72	5.26E+03
Silicon dioxide	SiO_2	60.09	3.19E+03
Silver (I) hydroxide	AgOH	124.91	1.59E+02
Uranyl hydroxide	$UO_2(OH)_2$	304.02	3.19E+02
Organic Compounds			
Benzene	C_6H_6	78.11	5.00E+02
Butanol & Isobutanol	C_4H_9OH	74.12	3.00E+03
Isopropanol	C_3H_7OH	60.09	3.00E+03
Methanol	CH_3OH	32.04	3.00E+02
Phenol	C_6H_5OH	94.11	1.00E+03
Tetraphenylborate	$B(C_6H_5)_4^-$	319.21	1.00E+03
Toluene	$C_6H_5CH_3$	92.13	5.00E+02
Tributylphosphate	$(C_4H_9)_3PO$	218.31	4.00E+02
Ethylene diamine tetraacetic acid (EDTA)	$((CO_2HCH_2)_2NCH_2)_2)$	292.25	5.00E+02

ANALYSIS METHODS AND COMPUTATIONS ASSUMPTIONS

METHODOLOGY:

Guidance provided in DOE Guide 151.1 (Ref. 3) has been incorporated into EMPP 6Q-001. Thresholds are used to eliminate the need to analyze insignificant hazards. The lowest quantity listed as a Threshold Quantity (TQ) in 29 CFR 1910.119 or 40 CFR 68.130; or, a Threshold Planning Quantity (TPQ) listed in 40 CFR 355 is the threshold for the chemical inventory (Ref. 4, 5, 6). Chemicals in the inventory not found in these three CFRs are not considered in this EPHA.

The screening of a chemical from further analysis does not necessarily mean that that chemical is not hazardous to human health. Relevant portions of Occupational, Safety, and Health Administration (OSHA), Resource Conservative Recovery Act (RCRA), and Comprehensive Environmental Response and Liability Act (CERCLA) regulations still apply to these materials.

Per EMPP 6Q-001, "If a container or storage vessel holds a mixture or solution of a chemical of concern, multiply the concentration of the chemical of concern, in weight percent, by the mass in the vessel to determine actual quantity for comparison to TQ/TPQ values."

Only chemicals with a TQ/TPQ value from Table 1 are given below in Table 2:

Table 2. Chemical Screening for Saltstone Facility with 6,504 Gallons

Chemical Name	Bounding Concentration (mg/l)	Total Inventory (lb)	Screening Quantity (lb)	Reference
Solvated Ions				
Mercuric oxide	2.07E+03	112	500	40CFR355 TPQ
Phenol	1.00E+03	54.3	500	40CFR355 TPQ

RESULTS

As all chemicals are below their respective TQ/TPQ values, all chemicals are screened from further analysis.

REFERENCES

1. *Standards For Development and Maintenance of an Emergency Preparedness Hazards Assessment*, EMPP 6Q-001, Rev. 4, Westinghouse Savannah River Company, Aiken, SC, July 2002.
2. Chandler, T.E., *Recommended Saltstone Facility Radiological and Chemical WAC and Permit Limits for Development of Tank 50H Material Balance (U)*, WSP-SSF-2004-00015, Rev. 1, Westinghouse Savannah River Company, Aiken, SC, July 15, 2004.
3. *Emergency Management Guide – Vol. II, Hazards Surveys and Hazards Assessments*, DOE G 151.1-1, U. S. Department of Energy , Washington, DC, August 1997.
4. "Labor," Process Safety Management of Highly Hazardous Chemicals, Code of Federal Regulations, 29 CFR, Part 1910.119, U.S. Department of Labor, Washington, DC, July 1999.
5. "Protection of Environment," Accidental Release Prevention Requirements: Risk Management Programs Under Clean Air Act, 40 CFR 68, U.S. Environmental Protection Agency, Washington, DC, July 1999.
6. The List of Extremely Hazardous Substances and Their Threshold Planning Quantities, 40 CFR 355, U.S. Environmental Protection Agency, Washington, DC, July 1999.

INTRODUCTION

The purpose of this calculation is to determine the radiological inventories for the Saltstone Facility for screening purposes and a plutonium-238 equivalent (Pu-238$_{eq}$) for any radionuclides that require further analysis. A review of the radiological inventories information is required by Emergency Management Program Procedure (EMPP)-6Q-001 (Ref. 1).

INPUT DATA

Radiological inventories for Saltstone Facility are obtained from Reference 2 and are given in Table 1. The Saltstone Facility Salt Feed Tank (SFT) is assumed to hold 6504 gallons. Conversion factors of 3785.412 ml/gal and 1E-12 pCi/Ci were assumed.

Table 1. Radiological Inventories for Saltstone Facility

Radionuclide	Inventory pCi/mL
H-3	6.26E+05
C-14	1.25E+05
Al-26	3.20E+03
Ni-59	1.25E+05
Ni-63	1.25E+05
Co-60	1.25E+06
Se-79	1.25E+05
Sr-90	2.50E+07
Y-90	2.50E+07
Nb-94	1.70E+04
Tc-99	4.69E+06
Ru-106	1.25E+06
Rh-106	Dose accounted for by parent nuclide
Sb-125	2.50E+06
Te-125m	2.50E+06
Sn-126	2.00E+04
Sb-126	2.00E+04
Sb-126m	2.00E+04
I-129	1.25E+05
Cs-134	1.25E+06
Cs-135	1.25E+06
Cs-137	1.32E+08
Ba-137m	Dose accounted for by parent nuclide
Ce-144	1.25E+05
Pr-144	1.25E+05
Pm-147	6.25E+06
Sm-151	2.50E+04
Eu-152	n/a
Eu-154	2.50E+06
Eu-155	1.25E+04
Ra-226	n/a

Table 1. Radiological Inventories for Saltstone Facility	
Radionuclide	**Inventory pCi/mL**
Ra-228	n/a
Ac-227	n/a
Th-229	n/a
Th-230	n/a
Th-232	3.20E+03
Pa-231	n/a
U-232	n/a
U-233	1.25E+04
U-234	1.25E+04
U-235	1.25E+02
U-236	1.25E+04
U-238	1.25E+04
Np-237	Bounded by Pu-239
Pu-238	Bounded by Pu-239
Pu-239	2.66E+05
Pu-240	Bounded by Pu-239
Pu-241	9.31E+05
Pu-242	Bounded by Pu-239
Pu-244	n/a
Am-241	Bounded by Pu-239
Am-242m	n/a
Am-243	Bounded by Pu-239
Cm-242	1.25E+04
Cm-244	Bounded by Pu-239
Cm-245	n/a
Cm-247	n/a
Cm-248	n/a
Bk-249	n/a
Cf-249	n/a
Cf-251	n/a
Cf-252	n/a
Total Transuranic Alpha Emitters	n/a
Total Beta-Gamma	n/a

ANALYSIS METHODS AND COMPUTATIONS

Table 2 shows the assumed maximum curie contents of each radionuclide.

Table 2. Radionuclides for Saltstone Facility with 6504 gallons Volume

Radionuclide	Inventory (pCi/ml)	Inventory (Ci)
H-3	6.26E+05	1.54E+01
C-14	1.25E+05	3.08E+00
Al-26	3.20E+03	7.89E-02
Ni-59	1.25E+05	3.08E+00
Ni-63	1.25E+05	3.08E+00
Co-60	1.25E+06	3.08E+01
Se-79	1.25E+05	3.08E+00
Sr-90	2.50E+07	6.16E+02
Y-90	2.50E+07	6.16E+02
Nb-94	1.70E+04	4.19E-01
Tc-99	4.69E+06	1.16E+02
Ru-106	1.25E+06	3.08E+01
Sb-125	2.50E+06	6.16E+01
Te-125m	2.50E+06	6.16E+01
Sn-126	2.00E+04	4.93E-01
Sb-126	2.00E+04	4.93E-01
Sb-126m	2.00E+04	4.93E-01
I-129	1.25E+05	3.08E+00
Cs-134	1.25E+06	3.08E+01
Cs-135	1.25E+06	3.08E+01
Cs-137	1.32E+08	3.25E+03
Ce-144	1.25E+05	3.08E+00
Pr-144	1.25E+05	3.08E+00
Pm-147	6.25E+06	1.54E+02
Sm-151	2.50E+04	6.16E-01
Eu-154	2.50E+06	6.16E+01
Eu-155	1.25E+04	3.08E-01
Th-232	3.20E+03	7.89E-02
U-233	1.25E+04	3.08E-01
U-234	1.25E+04	3.08E-01
U-235	1.25E+02	3.08E-03
U-236	1.25E+04	3.08E-01
U-238	1.25E+04	3.08E-01
Pu-239	2.66E+05	6.56E+00
Pu-241	9.31E+05	2.29E+01
Cm-242	1.25E+04	3.08E-01

Radiological Screening

Radionuclides are screened using the Screening Quantities (SQs) listed in 10 CFR 30.72 and employing the methodology identified in DOE STD-1027-92 as follows (Ref. 3, 4):

If the individual radionuclides are not in excess of their respective SQs and the sum of all the ratios of each radionuclide to that radionuclide's SQ is less than one (Eq. 1), then the entire inventory can be eliminated from further analysis.

$$\sum_{i=1}^{n} \frac{r_i}{SQ_i} < 1.0 \qquad \text{[Eq. 1]}$$

Where:

r = Inventory of individual isotope (Ci)
SQ = Screening Quantity for individual isotope (Ci)
n = number of isotopes

As given in Table 2, Pu-239 constituent in Saltstone Facility is 6.56 curies, which exceeds its screening value of 2. Therefore, all radiological materials within Saltstone Facility must be retained for further analysis.

Characterization of Material at Risk (MAR) for Airborne Dose

The MAR is characterized to determine a Pu-238$_{eq}$. This characterization reduces the number of consequence assessment runs required and simplifies the final source term calculation. The Pu-238$_{eq}$ is calculated using the following equation
(Ref. 1):

$$Pu-238_{eq} = \frac{1}{DCF_{Pu-238}} \sum_i (A_i)(DCF_i) \qquad \text{Eq. 2}$$

where:

$Pu\text{-}238_{eq}$ = The Pu-238 equivalent. Other isotopes may be used; however, Pu-238 is the historical choice for all but noble gases.

$DCF_{Pu\text{-}238}$ = The most restrictive Exposure-to-DCFs for Inhalation/Committed Effective Dose Equivalent (CEDE) per Unit Intake for Pu-238 (or other isotope) as taken from Federal Guidance Report 13 (Ref. 5).

A_i = The number of Curies of the *i*th isotope.

DCF_i = The Exposure to DCF for Inhalation for the *i*th isotope.

Using Eq. 2 above and the spreadsheet (Ref. 6), the Pu-238$_{eq}$ is calculated for the Saltstone Facility as given in Table 3. Those radionuclides that are used later in the analysis are in Bold type.

Table 3. Pu-238 Equivalent for Saltstone Facility per 6504 gal Volume

Radionuclide	**Inventory (Ci)**	**Inhalation DCF (rem/ci)**	**Total rem Factor**	**% Contribution to Dose**	**Pu-238eq (Ci)**
H-3	1.54E+01	1.44E-04	2.23E-03	0.00%	
C-14	3.08E+00	2.09E-03	6.43E-03	0.00%	
Al-26	7.89E-02	7.22E-02	5.69E-03	0.00%	
Ni-59	3.08E+00	1.32E-03	4.08E-03	0.00%	
Ni-63	3.08E+00	3.10E-03	9.57E-03	0.00%	
Co-60	3.08E+01	2.19E-01	6.74E+00	0.19%	
Se-79	3.08E+00	9.84E-03	3.03E-02	0.00%	
Sr-90	6.16E+02	2.39E-01	1.48E+02	**4.09%**	6.11E-04
Y-90	6.16E+02	8.44E-03	5.20E+00	0.14%	
Nb-94	4.19E-01	4.14E-01	1.74E-01	0.00%	
Tc-99	1.16E+02	8.33E-03	9.62E-01	0.03%	
Ru-106	3.08E+01	4.77E-01	1.47E+01	0.41%	
Sb-125	6.16E+01	1.22E-02	7.52E-01	0.02%	
Te-125m	6.16E+01	7.29E-03	4.49E-01	0.01%	
Sn-126	4.93E-01	9.95E-02	4.91E-02	0.00%	
Sb-126	4.93E-01	1.17E-02	5.78E-03	0.00%	
Sb-126m	4.93E-01	2.86E-05	1.41E-05	0.00%	
I-129	3.08E+00	1.74E-01	5.35E-01	0.01%	
Cs-134	3.08E+01	4.63E-02	1.43E+00	0.04%	
Cs-135	3.08E+01	4.55E-03	1.40E-01	0.00%	
Cs-137	3.25E+03	3.19E-02	1.04E+02	**2.88%**	8.15E-05
Ce-144	3.08E+00	3.74E-01	1.15E+00	0.03%	
Pr-144	3.08E+00	4.33E-05	1.33E-04	0.00%	
Pm-147	1.54E+02	3.92E-02	6.04E+00	0.17%	
Sm-151	6.16E-01	3.00E-02	1.85E-02	0.00%	
Eu-154	6.16E+01	2.86E-01	1.76E+01	0.49%	
Eu-155	3.08E-01	4.14E-02	1.28E-02	0.00%	
Th-232	7.89E-02	1.64E+03	1.29E+02	**3.59%**	4.18E+00
U-233	3.08E-01	1.35E+02	4.17E+01	**1.16%**	3.45E-01
U-234	3.08E-01	1.32E+02	4.08E+01	**1.13%**	3.38E-01
U-235	3.08E-03	1.23E+02	3.79E-01	0.01%	
U-236	3.08E-01	1.25E+02	3.86E+01	**1.07%**	3.20E-01
U-238	3.08E-01	1.18E+02	3.65E+01	**1.01%**	3.02E-01
Pu-239	6.56E+00	4.29E+02	2.81E+03	**78.09%**	1.09E+00
Pu-241	2.29E+01	8.25E+00	1.89E+02	**5.25%**	2.10E-02
Cm-242	3.08E-01	1.73E+01	5.32E+00	0.15%	
Total			3.60E+03	98.29%	**6.60E+00**

RESULTS

The radiological materials present in Saltstone Facility exceed the screening quantities and are, therefore, retained for further analysis. The Pu-238eq for Saltstone is 6.60E+00 Ci per 6504 gal volume.

REFERENCES

1. *Standards for Development and Maintenance of an Emergency Preparedness Hazards Assessment*, EMPP 6Q-001, Rev 4, Westinghouse Savannah River Company, Aiken, SC, July 2002.

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INTRODUCTION

This calculation develops ground level, downwind centerline doses for radionuclides releases from Saltstone Facility. The Hotspot dispersion code (Ref. 1) is utilized and all information is input as required by Emergency Management Program Procedure (EMPP) 6Q-001 (Ref. 2).

INPUT DATA AND ASSUMPTIONS

The following assumptions were used for benzene explosion scenario:

		Units
Tank Vol	7661	gal
Fill Factor	70.5	gal/in
Tank Inside Diameter	3.7	m
Benzene Concentration	2.72	vol %
Latent heat of vaporization of water	2257	kJ/kg
Specific volume of gas	22.4	l/mol
Specific combustion energy of benzene	757.5	kcal/mol
Waste Density	1.0	g/cm^3

The following conversion factors were used:

Conversion Factors	**Units**
12	in/ft
0.3048	ft/m
3.79	l/gal
4.186	kJ/kcal
1000	g/kg
3790	cm^3/gal

All consequence assessments use the Hotspot computer dispersion code.

From Calculation 2, the Pu-238 equivalent for Saltstone Facility is shown below in Table 1:

Table 1. Pu-238 Equivalent for Saltstone Facility per 6504 gal Volume					
Radionuclide	**Inventory (Ci)**	**Inhalation DCF (rem/ci)**	**Total rem Factor**	**% Contribution to Dose**	**Pu-238eq (Ci)**
Sr-90	6.16E+02	2.39E-01	1.48E+02	4.09%	6.11E-04
Cs-137	3.25E+03	3.19E-02	1.04E+02	2.88%	8.15E-05
Th-232	7.89E-02	1.64E+03	1.29E+02	3.59%	4.18E+00
U-233	3.08E-01	1.35E+02	4.17E+01	1.16%	3.45E-01
U-234	3.08E-01	1.32E+02	4.08E+01	1.13%	3.38E-01
U-236	3.08E-01	1.25E+02	3.86E+01	1.07%	3.20E-01
U-238	3.08E-01	1.18E+02	3.65E+01	1.01%	3.02E-01
Pu-239	6.56E+00	4.29E+02	2.81E+03	78.09%	1.09E+00
Pu-241	2.29E+01	8.25E+00	1.89E+02	5.25%	2.10E-02
Total			3.60E+03	98.29%	**6.60E+00**

ANALYSIS METHODS AND COMPUTATIONS ASSUMPTIONS

The calculated Source Terms (STs) are input to Hotspot for analysis under 95% Adverse and Average meteorological conditions. The 95% Adverse results are used to determine if an emergency threshold has been exceeded. Downwind distances for emergency classification are 30 m (Alert), distance to a Facility Boundary (Site Area Emergency [SAE]), and distance to the Site Boundary (General Emergency [GE]) (Ref. 2). In addition, the dose to the Central Training Facility (CTF) and Wildlife Management Area (WMA) are analyzed (Ref. 3, 4). The downwind receptors of interest are given in Table 2:

Table 2 Key Receptor Points

Alert	SAE	CTF	WMA	GE
30 m	130 m	1,200 m	9,660 m	9,980 m

Analysis that shows a classification trigger may be exceeded also includes graphical output for the downwind doses from the release. This output is included to allow dose estimates for other receptors of interest and determination of the maximum distance to 1 rem (distance to PAC).

Source Term Calculation

Radiological *ST* for discrete events are calculated using the following formula (Ref. 2):

$$ST = (MAR)(ARF)(RF)(DR)(LPF) \quad \text{[Eq. 1]}$$

where:

ST = Source Term (Ci of Pu-238_{eq})
MAR = Material at Risk
ARF = Airborne Release Fraction
RF = Respirable Fraction
DR = Damage Ratio
LPF = Leak Path Factor

The *MAR* is given in Table 1 for Saltstone Facility. The *ARF* is that fraction of the material that is released into the environment with the *RF* being that fraction of the *ARF* falling into the respirable range (typically ≤ 10μm). The *DR* is the amount of *MAR* that is involved during a postulated scenario. The *LPF* is a factor that can be used to take credit for holdup of material within some secondary confinement, filtration of the material released, or other phenomena that reduces the final amount of material released.

Rupture of a tank scenario is considered for Saltstone Facility in which the Salt Feed Tank catastrophically fails spilling its contents (6504 gallons). A median ARF (4E-5) and RF (0.7) were chosen from DOE Handbook 3010, Page 3-4 (Ref. 5). A free-fall spill was assumed with the solution having a density ~ 1.0 g/cm^3 (3-m fall distance). No credit is taken for building confinement or ventilation/filtration, thus, the LPF was also set to 1. A DR of 1.0 was conservatively assigned for the postulated conditions. This is an unfiltered release at ground level with a release duration of 10 minutes. The ST for the postulated scenario for a SST spill is given in Table 3.

Table 3. Source Term for Salt Feed Tank Spill Scenario

Release Designation	MAR (Ci)	DR	ARF	RF	LPF	Source Term (Ci)
1-RD-1	6.60E+00	1	4.00E-05	0.7	1	1.85E-04

A postulated explosion scenario is considered for Saltstone Facility in which the ventilation of the Salt Feed Tank fails and allows the benzene to build up. The scenario involves a waste tank full of vapor space, a benzene concentration of 2.72 vol % in the vapor space, and 1.0 g/cm^3 liquid density.

A deflagration was assumed instead of a detonation. Lees (Ref. 6) states that while detonations may occur in pipelines, they are improbable in vessels. In non-baffled vessels there are no obstructions causing turbulence and flame acceleration. Transition to detonation is therefore not likely in vessels, unless the gas is very detonable, the gas cloud is large, the cloud is jet ignited, or the vessel contains obstacles. In addition, the indicators for an explosion would be the same whether a detonation or a deflagration. Since the deflagration is far more likely, it was assumed.

The model states that the energy from the deflagration is used to vaporize the solution. The MAR x DR is the amount of liquid vaporized. As the liquid is vaporized, an amount equal to 0.1 of the vaporized liquid will become aerosolized (ARF= 0.1) and all the airborne particles are assumed to be respirable (RF=1). Since there was no credit taken for any aerosol removal mechanism, the LPF is conservatively assumed to be 1.

The amount vaporized is given by the following equation (Ref. 7):

$$M_v = MARxDR = \frac{Fn_b E_c}{h_{fg}} \qquad \text{[Eq. 2]}$$

where:

M_v = mass of vaporized liquid, kg
n_b = number of moles of benzene
E_c = specific energy of combustion for benzene, kJ/mole
h_{fg} = latent heat of vaporization of water, kJ/kg
F = fraction of energy deposited on liquid surface

Only a fraction of the energy from the deflagration is deposited to the liquid. The rest of the energy is deposited to the tank ceiling and side wall. Therefore, the energy deposition factor is calculated from:

$$F = \frac{A_l}{A_v} \qquad \text{[Eq. 3]}$$

where:

A_l = area of liquid surface = $\dfrac{\pi D_i^2}{4}$, m^2
D_i = inside diameter of tank, m
A_v = surface area (liquid, ceiling, and side wall) contacted by vapor space
$= 2A_l + \pi D_i (h_t - h_w)$, m^2
h_t = tank height, m
h_w = waste height, m

The vapor volume is calculated from:

$$V_v = V_t - V_w = V_t - \text{fill x } h_w \qquad \text{[Eq. 4]}$$

Where:

V_v = vapor volume, gal
V_t = tank volume, gal
V_w = waste volume, gal
fill = fill factor, gal/in

Therefore, the volume of benzene in the tank is:

$$V_b = (C_b/100)V_v \text{ x } 3.79 \text{ l/gal} \qquad \text{[Eq. 5]}$$

Where:

V_b = volume of benzene, liters
C_b = benzene concentration, vol %

Since the specific volume of gas (v_{gas}) at STP is 22.4 liters/mole, the number of moles of benzene is:

$$n_b = V_b/v_{gas} \qquad \text{[Eq. 6]}$$

Using a low temperature is conservative since it maximizes the number of moles of benzene in the vapor space.

The specific combustion energy of benzene (757.5 kcal/mole) is converted to kJ/mole by using a multiplication factor of 4.186 kJ/kcal. The mass of water vaporized can then be calculated from equation 2 as E_c and h_{fg} are inputs and F has been determined from equation 3 and n_b from equation 6.

The source term (in kg) can then be calculated from equation 1 since all the terms are now known. The total source term (Ci Pu-238 eq) is calculated as given below:

$$ST_{Ci\ Pu-238eq} = \frac{\text{Pu - 238 eq} \times ST_{kg}}{\text{Density}} \times CF \times ARF \times RF \times DR \times LPF \qquad \text{[Eq. 7]}$$

where:

CF = conversion factors

The mass of vaporized liquid at various vapor volumes are calculated as given in Attachment A. Attachment A shows the mass of water vaporized highest with the most vapor space in the tank. Therefore, the total ST for SFT is calculated using the mass of water vaporized with the maximum vapor space as given in Table 4. This is an unfiltered release at ground level with a release duration of 3-minutes.

Table 4. Source Term for Salt Feed Tank Explosion Scenario

Release Designation	Pu-238 eq * (ci/gal)	ST (kg)	Density (g/cm^3)	ARF*RF	DR	LPF	ST (Ci Pu-238 eq)
1-RD-2	1.02E-03	10.06	1.00	0.1	1	1	2.69E-04
* -6.60E+00 Ci/6504 gal							

Dispersion Modeling Parameters

General plume dispersion modeling parameters are as follows (Ref. 2):

95% Adverse and Average meteorology for ground level releases are as follows:

<u>95% Adverse</u>
E stability class; 1.7 m/s wind speed; 300 m inversion layer (Ref. 8)
<u>Average</u>
C stability class; 2.5 m/s wind speed; 500 m inversion layer (Ref. 8)

Reference wind speed 2 meters for ground level releases.

Ground-level release height is at 0 m.

Complex source term geometry is used.

Dry deposition and city terrain options are used.

Since the source term already has a release fraction applied, a value of 1.0 is input for modeling.

A 3-m by 3-m source term geometry is used.

Filter % is zero.

Deposition velocity of 1 cm/s is used.

Receptor height of zero is used.

RESULTS AND CONCLUSION

The consequences for Saltstone Facility are given in Table 5 below as well as in the Attachment B. All results are below 1 rem at all of the distances of interest. Therefore, the results did not show a potential for classifiable operational emergencies.

Table 5. Consequence Assessment Results

Release Designation	Met.	Dose @ 30 meters (rem)	Dose @ FB (rem)	Dose @ CTF (rem)	Dose @ WMA (rem)	Dose @ SB (rem)	Max. Distance to 1 rem (meter)	Probable Event Class
1-RD-1	Adverse	2.8E-01	2.5E-02	5.4E-04	3.3E-05	3.1E-05	10	None
1-RD-2	Adverse	5.2E-01	4.6E-02	1.0E-03	6.0E-05	5.8E-05	20	None
Met. = Meteorology								

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Attachment A

	A	B	C
Row No.	**Input**		**Units**
4	Tank Vol	7661	gal
5	Fill Factor	70.5	gal/in
6	Waste Height	2.34	m
7	Tank Height	2.7	m
8	Tank Inside Diameter	3.7	m
9	Benzene Concentration	2.72	vol %
10	Latent heat of vaporization of	2257	kJ/kg
11	Specific volume of gas	22.4	l/mol
12	Specific combustion energy of	757.5	Kcal/mol
	Calculations		
17	Liquid Surface Area	10.75	m^2
18	Vapor Surface Area	25.63761363	m^2
19	Energy Deposition Factor	0.419175129	
20	Waste Volume	6504	gal
21	Vapor Volume	1157	gal
22	Vapor Volume	4379.25	l
23	Benzene Volume	119.12	l
24	Total Mole of Benzene	5.32	mol
25	Combustion Energy of Benzene	16861.72	KJ
26	Mass of water Vaporized	3.13	kg

	A	B	C
Row No.	Input		Units
4	Tank Vol	7661	gal
5	Fill Factor	70.5	gal/in
6	Waste Height	=I5	m
7	Tank Height	2.7	m
8	Tank Inside Diameter	3.7	m
9	Benzene Concentration	2.72	vol %
10	Latent heat of vaporization of water	2257	kJ/kg
11	Specific volume of gas	22.4	l/mol
12	Specific combustion energy of benzene	757.5	Kcal/mol
	Calculations		
17	Liquid Surface Area	=3.14*(B8/2)^2	m^2
18	Vapor Surface Area	=2*B17+(3.14*B8*(B7-B6))	m^2
19	Energy Deposition Factor	=B17/B18	
20	Waste Volume	=(B5*12/0.3048)*B6	gal
21	Vapor Volume	=B4-B20	gal
22	Vapor Volume	=B21*3.785	l
23	Benzene Volume	=(B9/100)*B22	l
24	Total Mole of Benzene	=B23/B11	mol
25	Combustion Energy of Benzene	=B12*B24*4.186	KJ
26	Mass of water Vaporized	=B19*B25/B10	kg

Where I5 is the cell of the converted waste height of interest in meter.

The mass of water vaporized above is calculated for waste height of 6504 gal (2.34 m). The table below will shows the mass of water vaporized for various waste heights.

Waste Height (gal)	Waste	ST (kg)
6504	2.34	3.13
6000	2.16	4.15
5000	1.80	5.78
4000	1.44	7.03
3000	1.08	8.02
2000	0.72	8.83
1000	0.36	9.50
500	0.16	9.79
0	0.00	10.06

As given above the mass of water vaporized is highest with the most vapor space in the tank. Since the time to generate vapor is unknown. Therefore, the total ST for SFT is calculated using the mass of water vaporized with the maximum vapor space.

Release Designation	**Pu-238 eq * (ci/gal)**	**ST (kg)**	**Density (g/cm^3)**	**ARF*RF**	**DR**	**LPF**	**ST (Ci Pu-238 eq)**
1-RD-2	1.02E-03	10.06	1.00	0.1	1	1	2.69E-04
* - 6.60E+00 Ci/6504 gal							

$$ST_{Ci\ Pu-238\ eq} = \frac{Pu-238\ eq\ (Ci/gal) \times ST\ (kg) \times ARF \times RF \times DR \times LPF}{Density\ (g/cm^3)\ \times \dfrac{1\ kg}{1000\ g} \times 3790\ (cm^3/gal)}$$

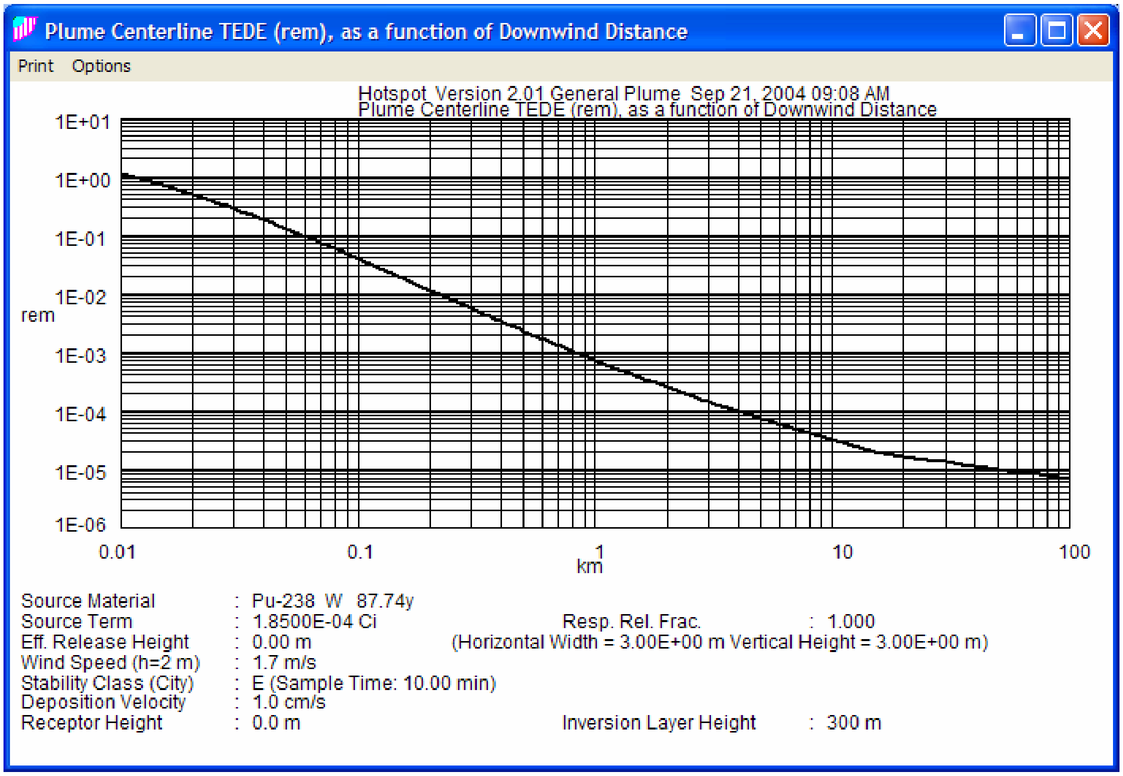
Attachment B

1-RD-1 Adverse Met.

```
Hotspot  Version 2.01 General Plume
Sep 21, 2004 09:07 AM

Source Material             : Pu-238  W   87.74y
Source Term                 : 1.8500E-04 Ci
Airborne Fraction           : 1.000
Respirable Fraction         : 1.000
Respirable Release Fraction: 1.000
Vertical Height             : 3.00E+00 m
Horizontal Width            : 3.00E+00 m
Effective Release Height    : 0.00 m
Wind Speed (h=2 m)          : 1.7 m/s
Distance Coordinates        : All distances are on the Plume Centerline
Stability Class (City)      : E
Respirable Dep. Vel.        : 1.00 cm/s
Non-respirable Dep. Vel.    : 8.00 cm/s
Receptor Height             : 0.0 m
Inversion Layer Height      : 300 m
Sample Time                 : 10.000 min
Breathing Rate              : 3.33E-04 m3/sec
Maximum Dose Distance       :   0.010 km
MAXIMUM TEDE                :   1.1 rem
FGR-11 Dose Conversion Data
Note: Dose data in TEDE column includes 4 days of ground shine (100% stay time).
```

DISTANCE km	T E D E (rem)	TIME-INTEGRATED AIR CONCENTRATION (Ci-sec)/m3	GROUND SURFACE DEPOSITION (uCi/m2)	GROUND SHINE DOSE RATE (rem/hr)	ARRIVAL TIME (hour:min)
0.030	2.8E-01	2.2E-06	2.2E-02	2.4E-10	<00:01
0.130	2.5E-02	1.9E-07	1.9E-03	2.1E-11	00:01
1.200	5.4E-04	4.1E-09	4.1E-05	4.6E-13	00:11
9.660	3.3E-05	2.5E-10	2.5E-06	2.8E-14	01:34
9.980	3.1E-05	2.4E-10	2.4E-06	2.7E-14	01:37

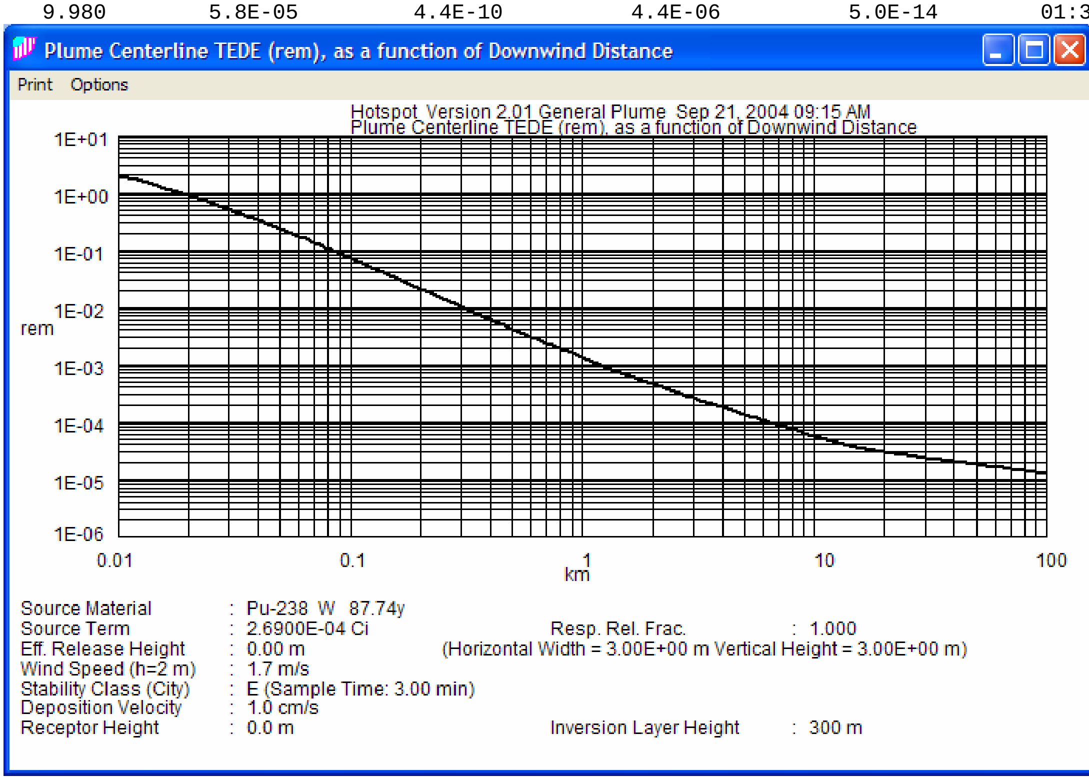


1-RD-2 Adverse Met.

```
Hotspot  Version 2.01 General Plume
Sep 21, 2004 09:14 AM

Source Material             : Pu-238  W   87.74y
Source Term                 : 2.6900E-04 Ci
Airborne Fraction           : 1.000
Respirable Fraction         : 1.000
Respirable Release Fraction: 1.000
Vertical Height             : 3.00E+00 m
Horizontal Width            : 3.00E+00 m
Effective Release Height    : 0.00 m
Wind Speed (h=2 m)          : 1.7 m/s
Distance Coordinates        : All distances are on the Plume Centerline
Stability Class (City)      : E
Respirable Dep. Vel.        : 1.00 cm/s
Non-respirable Dep. Vel.    : 8.00 cm/s
Receptor Height             : 0.0 m
Inversion Layer Height      : 300 m
Sample Time                 : 3.000 min
Breathing Rate              : 3.33E-04 m3/sec
Maximum Dose Distance       :   0.010 km
MAXIMUM TEDE                :   2.0 rem
FGR-11 Dose Conversion Data
Note: Dose data in TEDE column includes 4 days of ground shine (100% stay time).
```

DISTANCE km	T E D E (rem)	TIME-INTEGRATED AIR CONCENTRATION (Ci-sec)/m3	GROUND SURFACE DEPOSITION (uCi/m2)	GROUND SHINE DOSE RATE (rem/hr)	ARRIVAL TIME (hour:min)
0.030	5.2E-01	4.0E-06	4.0E-02	4.5E-10	<00:01
0.130	4.6E-02	3.5E-07	3.5E-03	3.9E-11	00:01
1.200	1.0E-03	7.6E-09	7.6E-05	8.5E-13	00:11
9.660	6.0E-05	4.6E-10	4.6E-06	5.1E-14	01:34
9.980	5.8E-05	4.4E-10	4.4E-06	5.0E-14	01:37



Appendix C

Emergency Preparedness Hazards Assessment Definitions

EPHA Definitions

The Emergency Preparedness Hazards Assessment utilizes some terms that may have meanings different from other safety documentation at the CST Facility. This appendix highlights important terms used.

Administrative Controls - Controls implemented as part of the facility management operating philosophy. These actions require human intervention to either prevent or limit the quantity released of a hazardous material. Examples of administrative controls include:

- procedural compliance
- access controls
- inventory control
- meteorological restrictions

Barriers - "Layers of protection" afforded facility/site personnel, the general public, and the environment by the design and operational controls of each facility. Facility design features that contain hazardous materials or separate them from people or the environment are physical barriers. Examples of these would include the following:

- tanks
- cylinders
- containment cells
- buildings
- piping systems

Committed Dose Equivalent (CDE) ($H_{T,50}$) - The dose equivalent calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem.

Note: 50-year committed doses are assigned to an individual in the year of the intake. For example: an individual receiving a 50-year committed dose of 5 rem from internally deposited Pu-238 in March of 1996 has the entire 5 rem assigned to their 1996 annual dose.

Committed Effective Dose Equivalent (CEDE) ($H_{E,50}$) - The sum of the committed dose equivalents to various tissues in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (w_T) - that is $H_{E,50} = \Sigma w_T H_{T,50}$. Committed effective dose equivalent is expressed in units of rem.

Note: The CEDE includes all intakes of radioactive material if there is more than one intake during a year.

Consequence - The result or effect (especially projected doses or dose rates) of a release of radioactive and/or hazardous materials to the environment.

Deep Dose Equivalent (DDE) - The dose equivalent derived from external radiation at a tissue depth of 1 cm in tissue.

Effective Dose Equivalent (EDE) (H_E) - The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factor (W_T) - that is ($H_E = \Sigma W_T H_T$). It includes the dose from radiation sources internal and/or external to the body. The effective dose equivalent is expressed in units of rem.

Emergency - The most serious event, consisting of any unwanted operational, civil, natural-phenomena, or security occurrence that could endanger or adversely affect people, property, or the environment.

Emergency Classification System - Standard classifications of nuclear and hazardous material related events, ranging in severity, used to communicate facility status. Each category is defined as follows:

- **Alert** - an Alert represents events in progress or having occurred that involves an actual or potential substantial reduction in the level of facility safety and protection. An Alert has occurred if an unplanned event results in hazardous material being released to the environment in concentrations that are expected to exceed Protective Action Criteria (PAC) at 30 meters from the point of release but that are less than a PAC at the facility boundary.
- **Site Area Emergency (SAE)** - represents events that are in progress or have occurred involving actual or likely major failure(s) of facility safety or safeguards systems needed for the protection of on site personnel, the public health and safety, the environment, or national security. Any environmental releases of hazardous materials are expected to exceed the appropriate PAC at or beyond the facility boundary but are not expected to exceed the appropriate PAC at or beyond the site boundary.
- **General Emergency (GE)** - represents events that are in progress or have occurred that involve actual or imminent catastrophic failure of facility safety systems with potential for loss of confinement integrity, catastrophic degradation of facility protection systems, or catastrophic failure in safety or protection systems threatening the integrity of a weapon or test device which could lead to substantial off site impacts. Any environmental release of hazardous materials can reasonably be expected to exceed the appropriate PAC at the site boundary.
- **Operational Emergency (OE)** - An event or condition that poses a significant hazard to safety, health and/or the environment and requires time-urgent response from outside the facility. An Operational Emergency involving release of significant quantities of hazardous materials may require further classification as an Alert, Site Area Emergency or General Emergency. The Emergency Duty Officer (EDO) in the SRS Operations Center is the Site categorization and reporting authority for Operational Emergencies that do not involve significant releases.
- **Courtesy Notification Event** - An event or condition that does not fall within the Operational Emergency categorization and classification system but has the potential for significant public or media interest.

Emergency Duty Officer (EDO) - A WSRC employee trained in emergency response actions and command and control functions, on duty 24 hours per day in the SRS Operations Center (SRSOC).

Emergency Response Planning Guideline (ERPG) - An estimate of the concentration ranges above which one could reasonably anticipate observing adverse effects, as described in the definitions for ERPG-1, ERPG-2, and ERPG-3, as a consequence of exposure to the specific substance. ERPG values are the preferred guidelines when dealing with chemical exposures; however, ERPGs exist for relatively few chemicals. Temporary Emergency Exposure Limits (TEELs) are approved for use as an equivalent. With the exception of recommended averaging time[1], TEEL-1, TEEL-2, and TEEL-3 have the same definitions as the equivalent ERPGs. The most recent TEEL list may be found on DOE's Chemical Safety home page (http://tis-hq.eh.doe.gov/web/chem_safety/), under "Documents".

NOTE: ERPGs are to be used for emergency planning -- not for determining exposure limits for personnel.

- **ERPG-1/TEEL-1 -** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
- **ERPG-2/TEEL-2 -** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
- **ERPG-3/TEEL-3 -** The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

The evaluation of the effects of hazardous chemical exposure is not as well defined as that of radiation effects. There is no standard protective action criterion or effectiveness rating for chemicals that is similar to the one used for radiation. This is because of the multitude of chemicals and hazardous materials and substances.

Event-based EALs - Address the occurrence of discrete events with potential safety significance. The level of severity is determined by the degree to which hazardous material confinement barriers are either failed or challenged as a result of the event and the ability of personnel to gain control of the situation. Methods/instrumentation available to detect and quantify event-initiating conditions are often limited. The resulting EAL definitions are stated in terms of the overall event descriptor.

Facility Boundary - Takes into consideration both material processing operation boundaries and physical barriers (i.e. structural or geographical). For emergency planning purposes, several structures or component units with a common purpose constitute a single facility.

[1] It is recommended that the peak fifteen-minute time-weighted average concentration at the receptor point of interest be used for comparison with the TEEL value.

Hazardous Material - Any solid, liquid, or gaseous material that is toxic, flammable, radioactive, corrosive, chemically reactive or unstable upon prolonged storage in quantities that could pose a threat to life, property or the environment.

Material at Risk (MAR) - The amount of hazardous material that is available to be acted on by a given physical stress. In an accident analysis, the MAR is multiplied by the appropriate release fraction to determine the source term.

Mitigative Features - These are controls that are set in place to maintain the safe configuration of the system. These are basically intrinsic or engineered actions/systems that do not require human intervention to either prevent or limit the quantity released of a hazardous material. Examples of mitigative features would include:

- segregated storage
- process control systems/interlocks
- HVAC systems
- bermed/diked areas surrounding process vessels
- security systems

Plutonium-238 Equivalent (Pu-238$_{eq}$) – An analytic technique of summing the inhalation dose potential from all the isotopes of interest in a source term into a single “equivalent” isotope in order to facilitate quick consequence assessment of that source term.

Protective Actions - Those actions taken to avoid or reduce a projected or actual exposure. Protective actions are used to ensure the physical safety of personnel and facilities during radiological or hazardous material incidents. Protective actions are formulated after determining a projected dose. They are only taken when the benefits of the protective action outweigh doing nothing or are sufficient to offset the possible undesirable consequences resulting from not implementing the protective action.

Protective Action Criteria (PAC) - Radiological dose or toxic material concentration level that acts as a trigger, for the receptor point of interest, to declare an operational emergency and initiate the recommendation or issuance of protective actions to protect workers or the general public. The Protective Action Criteria that pertains to SRS onsite and offsite radiological and chemical exposure are as follows:

- For a radiological hazard, 1 rem Total Effective Dose Equivalent (TEDE) or 5 rem Effective Dose Equivalent (EDE) Thyroid is the trigger for declaration of operational emergencies and off-site protective action recommendations. The onsite precautionary protective action criteria uses the limit of 100 mrem TEDE or 500 mrem EDE Thyroid as the initial trigger to clear an area of non-essential workers as a precaution against worsening conditions.
- For a chemical hazard, the limit of ERPG-2 or equivalent value is used as the trigger for declaration of operational emergencies and off-site protective action recommendations. The onsite precautionary protective action criteria uses the limit of ERPG-1 as the trigger to clear the area of non-essential workers as a precaution against worsening conditions.

Primary Barrier - The barrier that is closest to the material. For gases or liquids, this would be a tank or cylinder. This barrier keeps the material in its physical form or shape.

Receptor Locations - Three receptor locations have been established - the site boundary, the facility boundary and 30 meters from the edge of the spill or the point of release. These receptor locations can be used in classifying an emergency. The threshold between emergency classes is defined in terms of actual or potential consequences from a release of hazardous material resulting in protective action criteria (PAC) being exceeded at or beyond each receptor. Consequences at these locations form the basis for emergency planning and preparedness. Receptor locations are analyzed for each facility and for transportation incidents occurring within the facility boundary.

- 30 meters from the release (or edge of spill): the threshold for an incident that requires emergency response organization involvement (i.e., Alert).
- The facility boundary: the demarcation between a facility and its vicinity and the remainder of the site. The facility boundary receptor is the demarcation between an Alert and a Site Area Emergency.
- The closest site boundary: the nearest location to the facility where SRS does not have ownership and control over access. The site boundary receptor is the demarcation between a Site Area Emergency and a General Emergency.

Release - Normally an airborne release, as this pathway typically is the most time-urgent and requires rapid, coordinated emergency response on the part of the facility, collocated facilities, and surrounding jurisdictions to protect workers, the public, and the environment. Releases to aquatic and ground pathways, in most instances, do not have the same time urgency as airborne releases. When a release to an aquatic or ground pathway could have a near-term effect (i.e. through a community water supply), then it is considered in the hazards assessment.

Release Fraction - the coefficient used to estimate the amount of hazardous material (material at risk) suspended in air and available for airborne transport under a specific set of induced physical stresses. The release fraction is a combination of the fraction of the material released (Airborne Release Fraction [ARF]) and the fraction of the material that is respirable (Respirable Fraction [RF]).

Safeguards and Security Phase Declarations - The four emergency phases used by Security Forces for safeguards and security incidents and one non-emergency for purposes of graded response. The safeguards and security phase declarations and anticipated response actions are:

- <u>Security Alert</u> - An event requiring management attention and increased security vigilance but no emergency response actions (non-emergency condition).
- <u>Phase I</u> - A potential threat has been identified that warrants increased management awareness and requires heightened capability to implement security response actions (non-emergency condition).
- <u>Phase II</u> - A known threat has been identified that requires heightened capability to implement security response actions (generally equates to an Alert emergency classification).

- Phase III - A major verified security incident is in progress or has occurred that requires the immediate implementation of security response actions (generally equates to an SAE).
- Phase IV - A major verified security incident is in progress or has occurred that requires special operations procedures (generally equates to a SAE or GE, depending on the Facility).

Scenarios - Combinations of events and conditions that could cause release of each hazardous material characterized.

Site Boundary - In general, the perimeter of DOE-owned and controlled land is the site boundary. If the general public can gain unescorted access to areas of the site, such as visitors centers, these areas should be considered as offsite for purposes of emergency class definition, unless it is assured that those areas can be evacuated and access control established within about one hour of any emergency declaration.

Source Term - The amount of respirable material released to the environment. In an accident analysis, the source term is equal to the material at risk (MAR) multiplied by an appropriate source release fraction (ARF x RF). Source term =(MAR)(ARF x RF). Within classification procedures, the source term is typically expressed in an equivalent isotope of Pu-238 ($Pu\text{-}238_{eq}$).

Symptomatic Based EALs - Dependent upon one or more observable conditions or parameter values that are measurable over some continuous spectrum. They are often the same indicators utilized by operations personnel to monitor routine facility operation.

Total Effective Dose Equivalent (TEDE) - The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). Deep dose equivalent to the whole body may be used as effective dose equivalent for external exposures. For accidents associated with most SRS facilities, the CEDE calculated by SRS dispersion models is equivalent to the TEDE.

Appendix D

CEDE Versus TEDE

This calculation was prepared by Amber R. Martin on 12/22/1999 and reviewed by C. E. Shogren. This calculation explains how the Committed Effective Dose Equivalent (CEDE) calculated by the Hotspot Health Physics Codes is equivalent to the Total Effective Dose Equivalent (TEDE) called for in EPA-400 in regards the source terms found at the Savannah River Site.

CEDE Versus TEDE

Introduction

This calculation provides justification for the use of Committed Effective Dose Equivalent (CEDE) for the Protective Action Guide. Although analysis is based on historical data and distances at Savannah River Site (SRS), the contribution percentages estimated would be expected to vary insignificantly at alternative locations.

Analysis Methods And Computations

EPA 400, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, (Ref. 1) states the Protective Action Guides (PAGs) in terms of Total Effective Dose Equivalent (TEDE) not Committed Effective Dose Equivalent (CEDE). TEDE and CEDE are defined as:

> Total Effective Dose Equivalent (TEDE) - The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (CEDE) (for internal exposures). Deep dose equivalent to the whole body may be used as effective dose equivalent for external exposures.
>
> Committed Effective Dose Equivalent (CEDE) ($H_{E,\,50}$) - The sum of the committed dose equivalents to various tissues in the body ($H_{T,\,50}$), each multiplied by the appropriate weighting factor (w_T) - that is $H_{E,\,50} = \Sigma w_T H_{T,\,50}$. Committed effective dose equivalent is expressed in units of rem.

Within EPA 400 is the following statement concerning the various exposure pathways (inhalation, direct dose, etc.) and their relation to the PAG.

> Exposure pathways that make only a small contribution (e.g., less than about 10 percent) to the dose incurred in the early phase need not be considered. Inhalation of resuspended particulate materials will, for example, generally fall into this category.

This guidance has been used to eliminate the dose contribution from external exposures for the majority of accidents analyzed within the hazard assessment process. EMHA analysis therefore considers CEDE equivalent to TEDE.

This calculation quantifies the percent contribution to TEDE from external exposures. External exposures considered are:

- resuspension of deposited material
- direct shine from plume passage
- ground shine from material deposition

Resuspension Contribution

In order to determine the dose from resuspension to areas adjacent to the contamination footprint, the HOTSPOT Resuspension routine is used (Ref. 4). For determining the resuspension dose to individuals assumed to be in the centerline of the plume, a manual calculation based on the HOTSPOT methodology will be used. The following is a discussion on how HOTSPOT determines the source term from resuspension.

HOTSPOT utilizes an upwind virtual source term to model the initial distribution of the isotope of interest. The virtual-term point source is positioned at an upwind distance that results in a σ_y, at the center of the contamination zone, equal to 50% of the input effective radius (Figure 1).

The resuspension factor (S) for wind speed (u) at or below 3 m-sec^{-1} is calculated by:

$$S = (1.0\text{E}-04)\left(e^{-0.15\sqrt{t}}\right) + (1.0\text{E}-09) \qquad \text{[Eq. 1]}$$

where:

S = resuspension factor (m^{-1})
t = time since contamination event (days)

Resuspension as a factor of wind speed is calculated by:

$$S(u) = (S)\left(u/3\right)^2 \quad \text{for } u > 3 \text{ m-sec}^{-1} \qquad \text{[Eq. 2]}$$

$$S(u) = (S) \quad \text{for } u \leq 3 \text{ m-sec}^{-1} \qquad \text{[Eq. 3]}$$

Note: The resuspension factor can be determined empirically using measurements of the ground contamination (Ci-m^{-2}), and the radionuclide air concentration (Ci-m^{-3}) above the ground measurement location. The resuspension factor is then defined as the ratio of the air concentration to the ground concentration (m^{-1}).

Figure 1 is a graphical representation of how HOTSPOT creates a virtual source term in order to disperse the resuspension source term to downwind receptors.

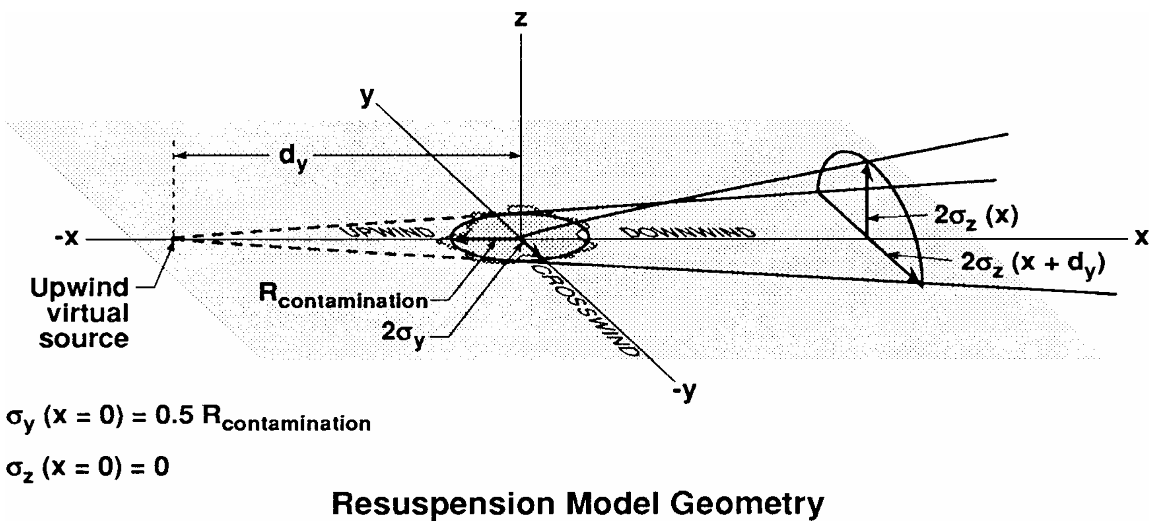


Figure 1

The effective source term (Q_{eff}) associated with the observed ground contamination (G) is calculated by:

$$Q_{eff} = \left(S(u)\right)(G)(\pi)\left(\sigma_{y,origin}\right)\left(\sigma_{z,origin}\right)(u) \qquad \text{[Eq. 4]}$$

where:

Q_{eff} = effective source term (Ci-sec^{-1})
G = ground contamination (Ci-m^{-2})
$\sigma_{y,origin}$ = standard deviation of the integrated concentration distribution in the crosswind direction at the origin (m)
$\sigma_{z,origin}$ = standard deviation of the integrated concentration distribution in the vertical direction at the origin (m)

The Gaussian standard deviations are evaluated at a distance equal to the distance from the origin to the upwind virtual source position. Q_{eff} can then be used in a typical Gaussian dispersion equation to estimate the radionuclide concentration downwind from the contamination. Within HOTSPOT, the 50-year committed dose is calculated per one-hour residence time. Therefore, an individual would be committed to the output dose for each hour at the selected receptor location. In order to calculate the resuspension percent contribution to the total CEDE, a HOTSPOT consequence assessment calculation was run using the following input parameters:

Stability class:	E
Wind speed:	1.7 m-sec^{-1}
Inversion layer:	200 m
Release time:	30 min
Source term:	10 Ci Pu-238
Release Height:	Ground level

Deposition velocity: 1 cm-sec^{-1}

Two receptor distances were selected for this evaluation. The first is a 670-m receptor that corresponds to the closest facility site boundary distance. The second distance is the average of the site boundary distance from facilities that are furthermost from the site boundary. This distance is 10,465 m. The resulting CEDE doses and contamination levels calculated by HOTSPOT at the receptors of interest are as follows:

Table 1: Baseline HOTSPOT Results

Receptor (m)	CEDE (rem)	Deposition (μCi-m^2)
670	170.0	1.1E+01
10,465	1.5	9.7E-02

In order to calculate the potential dose to an individual standing in the plume during the release, the concentration of Pu-238 in the air after plume passage needs to be manually calculated. As stated in the note after equation 3, the resuspension factor can be empirically determined by ratio of the ground contamination to the airborne concentration. As such, the airborne concentration (*A*) can be estimated by:

$$A = G\left(S(u)\right) \qquad \text{[Eq. 5]}$$

where:

A = airborne concentration (Ci-m^{-3})

G = ground contamination (Ci-m^{-2})

$S(u)$ = resuspension factor (1.0E-04 m^{-1} at t = 0)

For the 670-m receptor location, *A* is calculated by:

$$\left(11\ \mu\text{Ci - m}^{-2}\right)\left(1.0\text{E} - 04\ \text{m}^{-1}\right)\left(\text{Ci}/10^{6}\ \mu\text{Ci}\right) = 1.10\text{E-09 Ci-m}^{-3}$$

At 10,465 meter receptor *A* is calculated by:

$$\left(0.097\ \mu\text{Ci - m}^{-2}\right)\left(1.0\text{E} - 04\ \text{m}^{-1}\right)\left(\text{Ci}/10^{6}\ \mu\text{Ci}\right) = 9.70\text{E-12 Ci-m}^{-3}$$

The air concentration can be converted to a CEDE by use of the DCF contained within Reference 6. The most restrictive DCF listed for Pu-238 is 4.6E+08 rem-Ci^{-1} of uptake. Assuming a breathing rate (*BR*) of 1.2 m^3-hr^{-1} (Ref. 7), the estimated CEDE ($H_{E,50}$), in rem, to an individual for breathing a concentration (*A*) of airborne contamination for 1 hour is calculated by:

$$H_{E,50} = (A)(t)(DCF)(BR) \qquad \text{[Eq. 6]}$$

where:

A = airborne concentration (Ci-m^{-3})

t = time (hr)

DCF = dose conversion factor (rem-Ci^{-1})

BR = breathing rate (1.2 m^3-hr^{-1})

Using equation 6, the CEDE for the 670 m receptor is:

$$\left(1.10\text{E} - 09\ \text{Ci - m}^{-3}\right)\left(1\ \text{hr}\right)\left(4.6\text{E} + 08\ \text{rem - Ci}^{-1}\right)\left(1.2\ \text{m}^{3}\ \text{- hr}^{-1}\right) = 6.07\text{E-01 rem}$$

The CEDE for the 10,465 receptor is:

$$\left(9.70\text{E}-12\ \text{Ci - m}^{-3}\right)\left(1\ \text{hr}\right)\left(4.6\text{E}+08\ \text{rem - Ci}^{-1}\right)\left(1.2\ \text{m}^{3}\ \text{- hr}^{-1}\right) = 5.35\text{E-03 rem}$$

Table 1 was modified to include the resuspension CEDE for an unsheltered individual standing in the centerline of the plume for one hour after plume passage and the calculation of the percent contribution to the overall plume inhalation CEDE.

Table 2: Percent Contribution of Resuspension CEDE to Overall CEDE

Receptor (m)	CEDE (rem)	Contamination Levels (μCi-m^2)	1 hour Resuspension CEDE (rem)	Total CEDE(rem)	Resuspension %Contribution
670	170.0	11.0	0.607	170.61	0.36
10,465	1.5	0.097	0.00535	1.51	0.36

The resuspension factor used in these calculations (1.0E-04 m^{-1}) is considered a very conservative estimate for the potential airborne from surface contamination. The value is based on 1964 studies by J. Mishima and K. Stewart, cited in reference 8, and represents the maximum value observed during the study period. The 1.0E-04 m^{-1} value should be considered “bounding” and the above results should be applied to situations where the exposure is of a relatively short duration (e.g., several hours) to preclude excessive conservatism within the analysis.

Within EPA-400 is the following statement concerning the length of time to be considered for exposure to deposited radiological material during the incident phase of an emergency:

> Since the dose to persons who are not evacuated will continue until relocation can be implemented (if it is necessary), it is appropriate to include in the early phase the total dose that will be received prior to such relocation. For the purpose of planning, it will usually be convenient to assume that the early phase will last for four days -- that is, that the duration of the primary release is less than four days, and that exposure to deposited materials after four days can be addressed through other protective actions, such as relocation, if this is warranted. (Because of the unique characteristics of some facilities or situations, different time periods may be more appropriate for planning purposes, with corresponding modification of the dose conversion factors cited in Chapter 5.)

As stated, the “rule-of-thumb” is to use a default four day exposure period unless some other period can be justified. Based on the industrial types of accidents associated with ORNL Legacy Waste facilities, an accident event release time is expected to be on the order of only a few minutes to a few hours. As such, the four-day exposure period, which is based on reactor type accidents, can be justifiably reduced. Even though it has already been shown that the contribution of resuspension would be less than 10% for any reasonably conservative assumptions, it is still an interesting exercise to calculate the percent contribution of resuspension for the entire four days using a more appropriate resuspension factor.

Reference 10 contains one of the most comprehensive collections of studies performed to determine the release fractions and release rates of radioactive material due to natural and man-made events. Reference 10 discusses the resuspension of powders from soil due to wind and cites many studies.

Location	Source Material	Resuspension Factor Range (m^{-1})
Nevada Test Site GMX near center GMX near edge	Pu	 3.0E-10 3.0E-09
New York	Pu-238	5.0E-08
United Kingdom	Pu-238	5.0E-09
Palmares, Spain	Pu	1.4E-09 to 7.8E-06
Nevada Test Site Dusty rural air	Pu	 7.0E-06
Rocky Flats	Pu	1.0E-09 to 1.0E-05

The three highest values shown are 7.0E-06, 7.8E-06, and 1.0E-05 m^{-1}. As the actual distribution of data points for the above studies are not included in reference 10, thus eliminating the ability to "weigh" the above results, the highest resuspension factor listed is selected. Using the resuspension factor of 1.0E-05 m^{-1} equations 5 and 6 are utilized to determine the dose contribution of Pu resuspension.
For the 670-m receptor location, *A* is calculated by:

$$\left(11\ \mu\text{Ci - m}^{-2}\right)\left(1.0\text{E}-05\ \text{m}^{-1}\right)\left(\text{Ci}/10^{6}\,\mu\text{Ci}\right) = 1.10\text{E-10 Ci-m}^{-3}$$

At 10,465 meter receptor *A* is calculate by:

$$\left(0.097\ \mu\text{Ci - m}^{-2}\right)\left(1.0\text{E}-05\ \text{m}^{-1}\right)\left(\text{Ci}/10^{6}\,\mu\text{Ci}\right) = 9.70\text{E-13 Ci-m}^{-3}$$

Using equation 6, the CEDE for the 670 m receptor is:

$$\left(1.10\text{E}-10\ \text{Ci - m}^{-3}\right)\left(96\ \text{hr}\right)\left(4.6\text{E}+08\ \text{rem - Ci}^{-1}\right)\left(1.2\ \text{m}^{3}\ \text{- hr}^{-1}\right) = 5.83\text{E+00 rem}$$

The CEDE for the 10,465 receptor is:

$$\left(9.70\text{E}-13\ \text{Ci - m}^{-3}\right)\left(96\ \text{hr}\right)\left(4.6\text{E}+08\ \text{rem - Ci}^{-1}\right)\left(1.2\ \text{m}^{3}\ \text{- hr}^{-1}\right) = 5.10\text{E-02 rem}$$

Again, Table 1 was modified to include the resuspension CEDE for an individual standing unsheltered in the centerline of the plume for 96 hours after plume passage and the calculation of the percent contribution to the overall plume inhalation CEDE.

Table 3: Percent Contribution of Resuspension CEDE to Overall CEDE

Receptor (m)	CEDE (rem)	Contamination Levels (μCi-m^2)	96 hr Resuspension CEDE (rem)	Total CEDE (rem)	Resuspension %Contribution
670	170.00	11.0	5.83	175.83	3.30
10,465	1.50	0.097	0.051	1.55	3.30

<u>Direct External Dose And Ground Shine</u>

In order to show that the external exposure pathways contribute less than 10 percent to the total dose, the Dose Conversion Factors (DCFs) contained within chapter 5 of EPA 400 are compared to show their relative contributions.

Within the DOE Emergency Management Guidance for Hazards Assessments (Ref. 9), statements specifically aimed at the four day (96-hour) ground shine component are included, the guidance states:

EPA-400 provides for use of a TEDE ground shine component of less than four days, and for not including exposure pathways contributing less than 10 percent of the TEDE. The following procedure is recommended for determining how (or if) the ground shine component of the EDE is to be computed.

- If the full four-day ground shine component of TEDE can be shown to represent less than 10 percent of the TEDE, it may be excluded.
- If the full four-day ground shine component cannot be eliminated by applying the 10 percent rule above, the ground shine should be included for a period equal to the estimated EPZ evacuation time. If no official estimate of EPZ evacuation time exists, conservative estimates should be used.
- If ground shine values of less than four days are to be used, then the four-day DCFs in Section 5.6 of EPA-400 should be reduced proportionately (e.g., a 16-hour estimate of evacuation time would call for use of 16/96, or 0.17 times the DCF values).

As it is anticipated that evacuation time would be significantly less than four days, a 24-hour ground shine exposure is also determined for comparison purposes.

Table 4: Direct External Exposure and Ground Shine DCFs

Isotope	External Exposure DCF(1)	Inhalation Exposure DCF(1)	24-Hour Ground Shine Exposure DCF(1)	4-Day Ground Shine Exposure DCF(1)
Sr/Y-90	0.0E+00	1.6E+06	0.0E+00	0.0E+00
Cs-137	3.5E+02	3.8E+04	6.0E+03	2.4E+04
Pu-238	5.0E-02	4.7E+08	8.6E+00	3.4E+01

(1)DCF units are: rem-cm^3/μCi-hr

All of the DCFs are listed in the same units (based on an air concentration in μCi-cm^{-3}) and can be directly compared. The percent contribution to total dose for each exposure is listed in Table 5 with a 24-hour ground shine component and in Table 6 with a 96-hour ground shine component.

Table 5: Direct External Exposure and 24-Hour Ground Shine

Isotope	External Exposure % Contribution	Inhalation Exposure % Contribution	24-Hour Ground Shine Exposure % Contribution
Sr/Y-90	0.00	100	0.00
Cs-137	1.0	86.0	14.0
Pu-238	0.00	100	0.00

Table 6: Direct External Exposure and 96-Hour Ground Shine

Isotope	External Exposure % Contribution	Inhalation Exposure % Contribution	96-Hour Ground Shine Exposure % Contribution
Sr/Y-90	0.00	100	0.00
Cs-137	1.0	61.0	38.0
Pu-238	0.00	100	0.00

In the case of Cs-137, the ground shine component is significant. It is worth noting that in the cases where significant amounts of gamma emitters are encountered in an accident analysis, the analytical modeling used would calculate the external dose from immersion in the cloud in addition to the CEDE.

Results

Based on the above evaluation, the CEDE output from HOTSPOT, or other equivalent modeling, meets the EPA-400 requirements for calculation of the PAG and is considered equivalent to TEDE for the isotopes of interest at ORNL Legacy Waste facilities.

References

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10. *Airborne Release Fractions/Rates and Respirable Fractions for Non Reactor Nuclear Facilities*, DOE-HDBK-3010-94, December 1994.
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Appendix E

Technical Support Room
EAL Data

(Since consequence assessment did not identify any Classifiable Operational Emergencies [i.e., PAC are not expected to be exceeded at identified receptor locations], EALs are not required for Saltstone Facility.)